Digital Quality of Life

Understanding the Personal & Social Benefits of the Information Technology Revolution

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About the Information Technology and Innovation Foundation

ITIF is a non-profit, non-partisan public policy think tank committed to articulating and advancing a pro-productivity, pro-innovation and pro-technology public policy agenda internationally, in Washington DC and the states. Recognizing the vital role of technology in ensuring American prosperity, ITIF focuses on innovation, productivity, and digital economy issues.

Technological innovation, particularly in information technology, is at the heart of America's growing economic prosperity. Crafting effective policies that boost innovation and encourage the widespread "digitization" of the economy is critical to ensuring robust economic growth and a higher standard of living. However, as in any new and changing situation, policymakers have varied awareness of what is needed and what will work. In some cases legislators have responded to new and complex technology policy issues with solutions more suited for the old economy. And as the innovation economy has become increasingly important, opposition to it from special interests has grown. Finally, the excitement that the press, pundits and decision makers showed toward the information technology (IT) revolution in the 1990s has all too often been replaced with an attitude of "IT doesn't matter." It is time to set the record straight—IT is still the key driver of productivity and innovation.

As a result, the mission of the Information Technology and Innovation Foundation is to help policymakers at the federal and state levels to better understand the nature of the new innovation economy and the types of public policies needed to drive innovation, productivity and broad-based prosperity for all Americans.

ITIF publishes policy reports, holds forums and policy debates, advises elected officials and their staff, and is an active resource for the media. It develops new and creative policy proposals to advance innovation, analyzes existing policy issues through the lens of advancing innovation and productivity, and opposes policies that hinder digital transformation and innovation.

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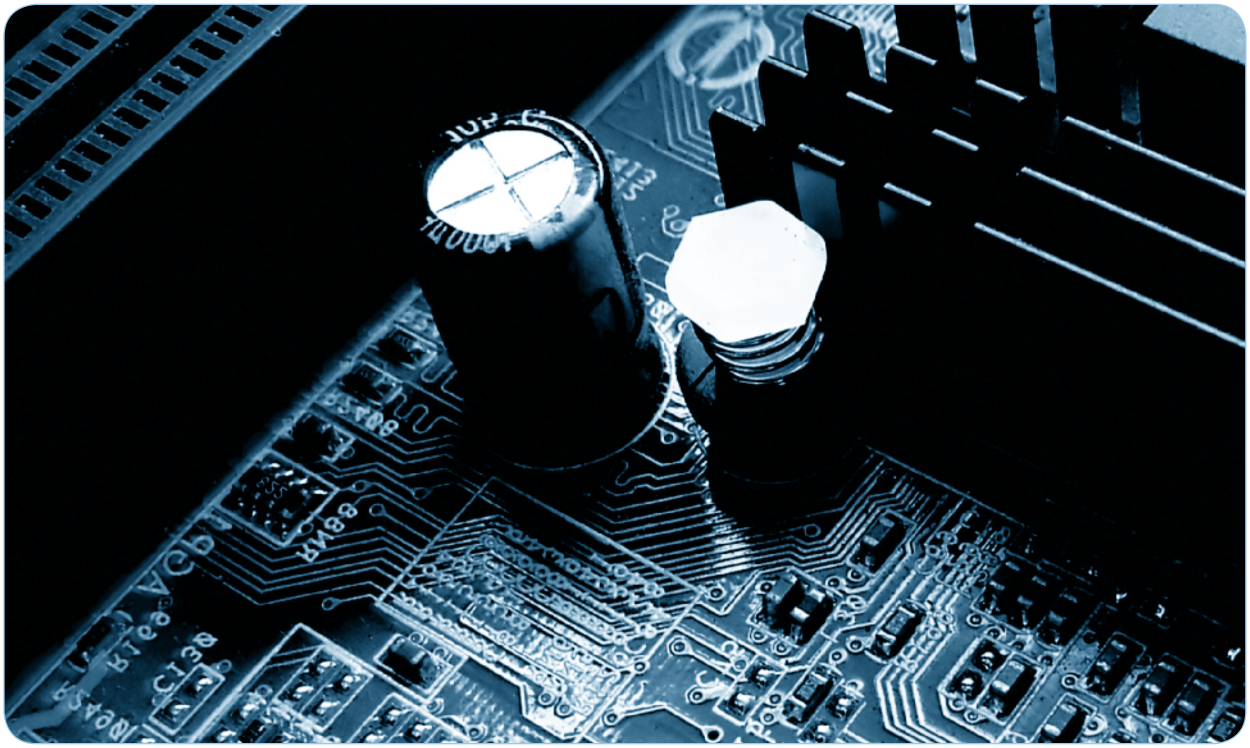

In the new global economy, information technology (IT) is the major driver of both economic growth and improved quality of life. The Information Technology and Innovation Foundation (ITIF) in its 2007 report *Digital Prosperity: Understanding the Economic Benefits of the Information Technology Revolution* documented how IT, since the mid-1990s, has been the principal driver of increased economic growth not only in the United States but also in many other nations.[1] In the present report, we show that IT is also at the core of dramatic improvements in the quality of life for individuals around the world: IT is the key enabler of many, if not most, of today's key innovations and improvements in our lives and society—from better education and health care, to a cleaner and more energy efficient environment, to safer and more secure communities and nations.

In the 1960s, if someone were asked to name the technology at the forefront of improving society and quality of life, she might have responded, as Mr. McGuire did in the movie *The Graduate*, "plastics." And indeed, in the old economy, breakthroughs in materials technologies such as plastics let organizations more easily manipulate "atoms" to create products that dramatically improved the quality of life for billions of people around the globe. Plastics gave us more durable and easy-to-use materials. Cars and appliances depended on low-cost steel. Aluminum enabled jet aviation. Breakthroughs in chemistry provided us with better drugs, household products, clothing, and a host of other improvements. In short, the "materials revolution" drove both economic growth and dramatic improvements in the quality of our lives.

Today, however, the materials revolution has largely achieved its promise, particularly in developed nations, and relatively few innovations rely on materials technologies. Certainly many advances in the IT revolution depend on hardware innovations made possible by continued advancement in materials technology, but these improvements are not manifest in the physical nature of these devices but rather in their functional performance. Thus the value found in newly-designed microprocessors has less to do with physical properties such as size, weight and durability and more to do with functional properties, such as the number of instructions processed per second. It is now the "digital information revolution" that is driving innovation and enabling billions of people to live better lives. More and better information has always had the potential to make our lives better, but until recently, the potential of an information-rich society remained something only utopians could dream about.

To be sure, advances in information technology have occurred throughout history—from Guttenberg's invention of moveable type, to the typewriter and telegraph, to the telephone and Xerox machine—making it easier and cheaper to create, manipulate, organize, transmit, store, and act on information. And with each information breakthrough, optimists heralded a new era. Thus, for example, with the rise of the railroad in the 19th century, sociologist Charles Fraser stated in 1880, "an agent is at hand to bring everything into harmonious cooperation, triumphing over space and time, to subdue prejudice and unite every part of our land in rapid and friendly communication...and that great motive agent is steam."[2]

Many information innovations occurred after World War II but information remained scarce and hard to use and transmit. The reason was that the processing of information relied on "atoms" to record or transmit information in analog form rather than the "bits" (binary digits of "1s" for on and "0s" for off) used to record or transmit information in digital form. Pen and pencil, industrial offset printers, and Xerox machines recorded information on paper. Needles made scratches in vinyl discs that could be rotated to hear sounds. Light came through a camera lens to excite atoms on chemically imprinted photo paper. Telephones translated voices into electric waves that could be played back on speakers.

At the time of their introduction, many analog information technologies were treated with well-deserved exhilaration. When compared to the quantum advancements of the last decade, though, these technologies now seem as archaic as cuneiform must have seemed to those in the industrial era. The digital information revolution enables a host of information in digital form—from a voice on a telephone, to a signal from a wireless sensor of pollution in a bay, to information on disease outbreaks—to be far more easily generated, transmitted, and analyzed than ever

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before in human history.

It is only now, when a vast array of information is in digital form and when it is far easier and cheaper to create, manipulate, organize, transmit, store and act on information that we can truly speak of being in the digital information age. The fact that your shoes can now communicate with your iPod when you are running, though seemingly trivial, is emblematic of the digital information revolution.[3] Yet, perhaps because of examples like shoes talking to MP3 players, it has recently become fashionable for skeptics to look askance at the digital information revolution, arguing that it's much ado about nothing and that it is a pale imitation of the really "great" innovations of the past.

At first glance, it appears that they are right. After all the materials revolution brought with it a host of amazing new "things": automobiles, planes, appliances, the telephone, etc. Both society as a whole and individual lives were dramatically different and better because of these. When compared to these world-changing innovations, IT doesn't measure up, so say these skeptics. But in holding the digital information revolution to the standard of "Does it produce big new things?" the skeptics miss the key point of the revolution, which is that most of the big innovations in "things" is over. Most of the things that can be developed have already been developed. But we have only begun to scratch the surface when it comes to making the world alive with information.[4]

Indeed, for the foreseeable future, the most promising advances will relate to the ability to use information more effectively. The materials revolution produced lifesaving vaccines, but the digital information revolution is enabling the creation of a rapid learning network to enable our global health care system to quickly find out what treatments work best and which don't. The materials revolution produced the automobile and the highway system, but the digital information revolution is creating intelligent transportation systems and is letting us "digitally travel" through telecommuting and teleconferencing. The materials revolution produced the telephone, but the digital information revolution is allowing ubiquitous communication from a wide range of devices and places.

In other words, the digital information revolution is not likely to produce a world that looks significantly different than the world of the recent past. But it is producing a world that functions in radically different and better ways, with individuals and organizations able to access and use a vast array of information to improve their lives and society. Indeed, after 5,000 years of civilization, we are only now moving from a relatively inert and obtuse world to one that is intelligent and "alive with information." So if the measure of a revolutionary technology is whether it changes "atoms," IT fails. But if the measure is the degree of change and improvement a technology system brings, the IT revolution ranks up there with revolutionary technologies of the past.[5]

So what will this intelligent and connected world bring? Clearly, the digital information revolution is opening up an amazing array of information for people to get access to, particularly through the Internet. But to see the information revolution as principally about the ability to more easily access text or video information is to only see the tip of the iceberg. Information access on the Internet is an amazing innovation, but the full breadth and depth of the digital information revolution goes far beyond Web surfing, for the digital information revolution is extending to virtually all aspects of our lives, all parts of society, all organizations and all nations.

Without question, much of how our lives and society work is based on information. A table saw that knows it should immediately stop if the operator's finger touches the blade is using information. A car that that senses if it is about to hit another car and automatically puts on the brakes is using information. A gun that lets only the owner fire it is using information. Sensors that measure water pollution in particular places and transmit that data to regulators and the public are using information. A mobile device that lets the owner know when her friends are nearby is using information. In short, making the world intelligent and more alive with information is the key to improved quality of life and social progress.

In a world saturated with information and with the tools to effectively get it and process it, we are entering a new era where IT is the major driver of progress and change in many areas of our lives and society, among them the following:

- **Improving our access to information.** IT is putting a variety of information at people's finger tips, whether they be students in Ghana accessing Massachusetts Institute of Technology course materials online without ever leaving their homes or people in Holland getting information online to help them better understand a medical condition. One can appreciate this development by noting that Wikipedia (the online encyclopedia that anyone can edit) has well over 2 million English articles with 3.4 million contributors (and versions in 190 other languages), while the 32 volumes of *Encyclopedia Britannica* contain approximately 65,000 articles.[6] Moreover, real-time language translation software is now letting people access information in languages other than their own.

- **Helping us sort out "the needles from the haystacks."** Although the digital revolution has led to an explosion of information and data, without the ability to make sense of it, much of the information and data would be as worthless as an academic library without a card catalogue. Luckily, powerful new software tools are letting data be analyzed to find patterns and connections. In health care, for example, IT systems are creating rapid learning networks to discover which medical treatments work best and which do not work at all.

- **Harnessing the power of markets.** Many areas of life are rightly insulated from markets, such as the workings of much of government and our home lives. But in many areas that involve consumer choices, markets can bring improved efficiency and quality. Well-functioning markets need information and transparency—and IT can provide both. Smart electricity meters can let electricity prices be based on time-of-day use so that consumers have incentives to consume less at peak periods, thereby reducing the need to produce additional peak-load power. Radio-frequency identification (RFID)-enabled recycling bins let communities provide rewards to citizens that recycle more of their trash. Global positioning system (GPS) navigation systems are letting vehicles be charged by the mile driven, providing a much better link between costs and prices. Web-enabled IT tools let consumers know more about the quality of a host of products and services—from health care to home repair services to airlines, and much, much more—enabling them to make smarter purchasing decisions.

- **Letting us substitute information for travel.** If the old economy brought about a revolution in travel, the new digital economy may be bringing about a revolution in the substitution of information for travel. By bridging distance, IT is letting a growing share of activities that used to require face-to-face presence to now be conducted at a distance, saving people time and money and saving society energy and space in offices, roads and airports. Telework is the fastest growing mode of "travel" to work, and millions of workers are choosing this option. "Telepresence" is letting people from around the world meet virtually with close to the same kind of interactions that once could only happen in face-to-face meetings. Telemedicine is bringing top-quality doctors to patients in remote areas; and telemonitoring is letting doctors monitor patient's conditions without having to always see them in person. In addition, e-commerce is giving businesses in rural areas access to markets around the world and giving consumers access to products around the world.

- **Giving us a vast array of choices.** Henry Ford is supposed to have once said that the customer can have any color Model T as long as it is black. Today, the IT revolution is giving people a wide variety of choices, enabling them to get the kinds of products and services that most fit their needs. Internet radio gives people the chance to move beyond the limited formats presented on local over-the-air radio and instead hear hundreds if not thousands of formats from around the world. E-commerce lets people buy a vast array of goods and services that previously might have been difficult to find at local stores. A growing array of educational software applications lets lessons be individually tailored to student needs in ways that classroom teachers never could.

- **Letting us know more things in real time.** The value of much information depends on its timeliness. Information on road traffic conditions is of little use if you learn it by being stuck in traffic. Knowing that a person on a terrorist watch list entered the nation a week ago is much less valuable than knowing when that person is standing at a customs desk trying to cross a border. Knowing that a factory emitted a much higher level of air pollution last month is of less value than knowing it when it happens. Knowing the actual water levels of local streams and rivers can help local officials have more time to prepare for flooding. In all of these and a host of other areas, IT is enabling information to be collected, organized, and presented in near real time, so that users can make the right decisions at the right time.

- **Letting us monitor our homes and loved ones.** Knowing that our homes and families are safe is perhaps the most important thing we want to know. Now IT is providing us with much greater security. Real-time detection systems can send information to our computers at work or our cell phones to let us know if an intruder is in our home. GPS-enabled cell phones can let parents know the location of their children, and in-vehicle systems can let parents know where their teenage children are driving and even how fast. IT systems can let people know whether their home environment is conducive to an asthma attack at any particular time. Webcams in daycare centers can let parents know how their children are doing throughout the day.

- **Letting us enjoy higher-quality goods and services.** While IT is making information more accessible, it is also dramatically increasing the quality of many goods and services, including making the economy more energy efficient. Significantly more precise medical imaging technology, enabled by IT, is allowing doctors to have much more accurate information about what is going on inside patients. IT is enabling cars to be more energy efficient and enabling new renewable energy technologies like wind power and solar technologies to be efficient. And though high-definition widescreen TVs may not rank up there with medical imaging or more energy-efficient cars in social importance, they do make our lives more enjoyable and entertaining, particularly at playoff time.

- **Making our lives safer.** Safety is often a matter of getting the right information at the right time. And IT is enabling a host of products to be safer. IT is enabling cars to be safer by letting drivers know in real time of impending problems. IT is enabling a host of products, including power table saws, guns, and pill bottles, to become safer. And IT is giving law enforcement and first responders better tools, including gunshot locator systems, chemical and biological weapons sensors, robots for bomb disposal, and integrated communication networks, to make our lives safer.

- **Improving convenience and saving time.** IT is saving people time and giving them new channels by which they can more conveniently conduct their daily lives in many ways: from allowing passengers to check themselves in at kiosks at airports, to allowing consumers to order products online, to allowing citizens to interact with government over the Internet.

- **Improving accessibility for people with disabilities.** A key challenge for many people with disabilities is directly related to difficulties in processing information. But IT is enabling millions of people with disabilities to live better lives. GPS navigation systems with voice prompts are bringing new mobility to individuals with visual impairments, while text-to-speech technology is helping them use computers. Individuals with a hearing disability (and their friends and family) can take advantage of online training to learn American Sign

Language. IT is even providing innovations that were recently only seen in science fiction: IT-enabled artificial retinas, for example, are restoring and improving vision in individuals with visual impairments; and IT-enabled artificial limbs are enabling people who have lost limbs to interact with their physical environment in ways never before thought possible.

- **Facilitating communication.** In the old economy, most communication other than face-to-face communication took place through the telephone and physical mail. Today communication choices have exploded. Cell phones now outnumber land lines around the world by more than 2 to 1.[7] There are nearly 57 billion non-spam e-mails sent daily worldwide, as opposed to 700 million pieces of mail handled daily by the U.S. Postal Service.[8] Police and other first responders can now communicate with each other more easily and thus can more easily make the right decisions at the right time. But it's not just person-to-person communication choices that have expanded; machine-to-person communication has expanded, as well. On-board vehicle communication systems can communicate with emergency operators if the vehicle is in a crash. Airline computers can call their customers' cell phones to let them know that their flight is delayed.

- **Giving people greater control over their own lives.** When information was scarce and often hard to understand, we had to rely on professionals or businesses to help find that information and hopefully make sense of it in ways that helped us. Now IT is liberating and empowering individuals to be able to more effectively take control of their own lives—from a farmer in India who gets real-time information on crop prices on his cell phone to a patient who gets the latest and best health information to enable her to take more responsibility for her own health care to a person in her living room using a digital video recorder so she can decide when she wants to watch a TV show.

- **Holding organizations accountable.** IT is enabling people to hold organizations accountable in a number of ways: from using cell phone cameras to document government acts of repression in dictatorships to being able to go online and use structured Web tools to provide feedback on what government should do. Cell phone cameras and inexpensive digital video cameras, combined with sites like YouTube, are providing a check on government and corporate abuses, from exposing police brutality to documenting abuse of animals in meat packing plants.

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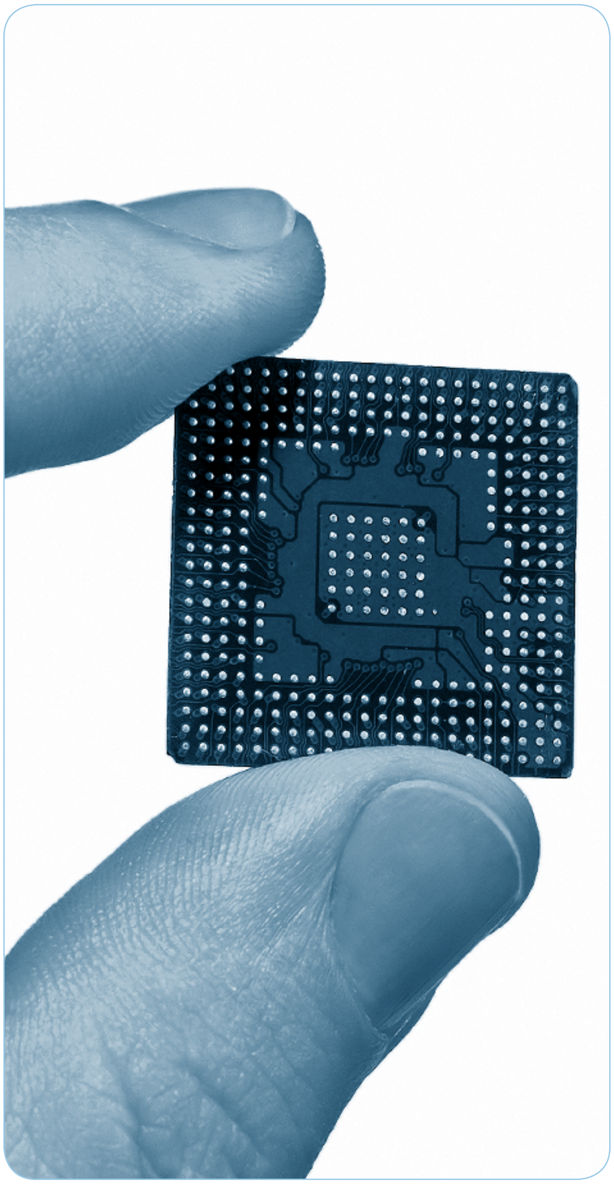
2. Why Is the Digital Information Revolution Happening Now?

Why is the information technology (IT) revolution creating a global information society now and not 20 years ago or 20 years from now? The answer is simple: Moore's Law. In 1965, Intel cofounder Gordon Moore observed that as transistors got smaller, the number of transistors that fit onto an integrated circuit grew exponentially. Moore challenged the semiconductor industry to continue this exponential growth—a challenge the industry has risen to time and again. In practical terms, with innovation, capital expenditure, and risk, the result has been that the computing power of a chip has doubled every 18 months.

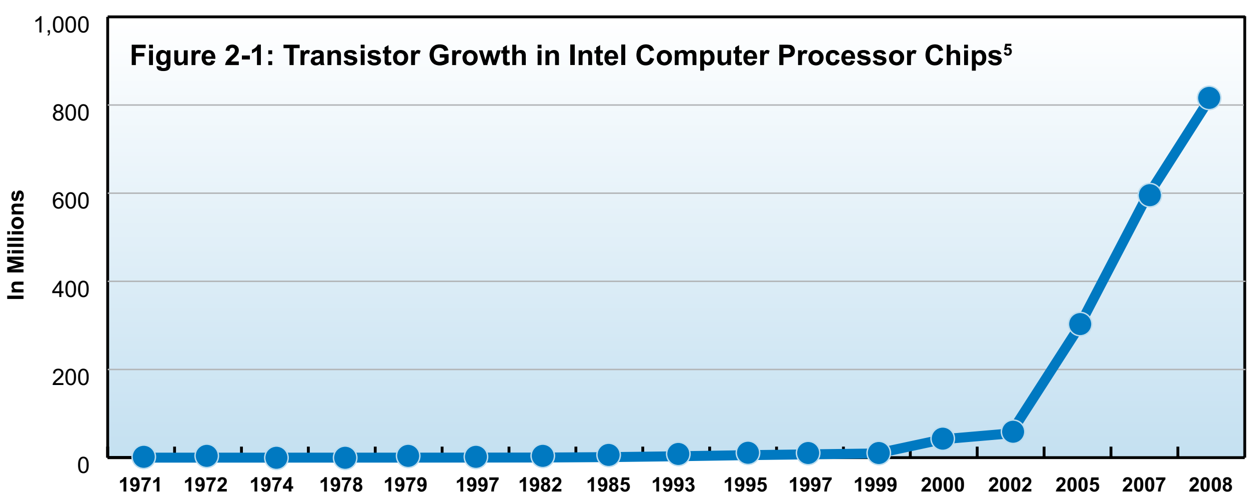


But it was not until the improvements inherent in Moore's law had reached a critical inflection point, around the mid-1990s, that we could speak of an IT revolution. Even after 25 years of steady progress, the digital technology of the early 1990s was still not powerful enough, cheap enough and easy enough to use to power an information revolution. In 1990, the cost of the Intel processor had fallen to around $20 per million instructions per second (MIPS), down from $480 in 1978. But this was still too expensive to enable the kinds of low-cost, high-performance devices and applications needed to make the world alive with information. Just 13 years later, in 2003, the cost per MIPS (of the Itanium 2 processor) had fallen by a factor of 10 to $2.[1] One reason for this change was the ability to pack even more transistors onto microprocessors (see Figure 1).

Exponential progress was not confined to processors—it extended to many other core IT technologies, including memory, storage, sensors, displays, and communications.[2] The real price of servers fell approximately 30 percent per year between 1996 and 2001. Hard-drive storage capacity has doubled every 19 months while the cost of a stored megabyte of data has fallen 50 percent each year. As a result, the cost of storing 1 megabyte of information fell from 17¢ in 1999 to half a cent in 2002 to less than 1/10th of a cent today. With these kinds of historically unprecedented price declines, it is now easy and cheap to do things that a decade ago were neither. Currently, for example, Microsoft provides around 5 gigabytes (5,000 megabytes) of free storage for users of its free MSN e-mail service, enough to store four or five full-length movies. If Microsoft were to provide this service today using 1995 technology (in 2008 prices), it would cost the company more than $5,500 per user. Today the company can provide the storage service for less than $1 per user.

Not only has IT become cheaper and more powerful, it has become much easier to use.[3] Through the mid-1970s, computers were considered complex devices that could be operated only by trained professionals. Operating a computer was often compared to flying a commercial jet because an operator needed years of training and a license—and anyone who took a close look at hardware and software prior to 1970 would have to conclude as much. But beginning in the mid-1970s and accelerating with the introduction of Apple's first Macintosh computer with a graphical user interface, things dramatically changed. Computers and their software were now designed for ease of use, which has made it possible for non-highly-trained people to exploit the benefits of IT. The trend toward more user-friendliness has continued and accelerated to this day, and IT is now moving in the direction of intuitive devices that will not even require familiarity with a mouse or a keyboard, only the ability to speak.

IT is even creating new ways to display and convey information. Cheap displays allow almost any device to output digital information, such as refrigerators that display recipes, shopping lists, and the "use by" date of the food stored inside. In some instances, the very concept of having an information-rich screen that users can actively interact with is being reworked to create products intended to integrate information seamlessly into daily life. One such product designed by engineers is an umbrella



that uses a wireless data radio to get the forecast and then glows when it is supposed to rain so it does not get left behind. Another device, the Ambient Orb, is a frosted glass ball that can be set up to glow different colors based on a preselected variable, like showing one color if the stock market or a particular stock is up and another if it is down. The same concept can also be applied to products that utilize data like the forecast, pollen count, and traffic congestion.

Two other key developments are enabling this digital information revolution: cheap networked sensors and global positioning systems (GPS). The availability of cheap, powerful sensors that can detect everything including chemicals, temperature, traffic, sounds, wind, and images means that it is easier to detect and process information about the environment. In addition, the availability of low-cost GPS devices means that devices can move beyond stationary data collection and allow mobile data collection where information can be associated with a specific time and place.

One final piece of the puzzle that enables the emergence of the information society is now being put in place: lots of bandwidth at low costs. It is one thing if IT is easy to use and cheap, but unless information can be cheaply transmitted, both wirelessly and by wire, information flows will be severely limited. Luckily, bandwidth costs have fallen significantly. In Japan, the average consumer can subscribe to 100 megabits per second (Mbps) fiber-optic cable service for around $40 per month. In 2001, a 1.5 Mbps per month T1 line in the United States could cost as much as $1,000 per month.[5] Seven years later, U.S. consumers can get broadband speeds 10 times as fast for 1/25th of the cost.

In sum, it was only when dramatic reductions in costs and improvements in the usability of IT occurred that the digital information revolution really began to take off in this decade.

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3. Public Policy Principles for Driving Digital Quality of Life

Information technology (IT) is the most important factor driving improvement in a wide array of areas critical for the quality of life for individuals and healthy societies. But by and large, policymakers have not fully appreciated the extent to which IT is driving change and enabling improvements, nor the impact—pro or con—that public policy can have on this development. Though it is beyond the scope of this report to lay out a detailed policy blueprint for IT-enabled change, it is imperative that policymakers around the globe need to follow at least ten key principles if their citizens and societies are to fully benefit from the digital revolution. To ignore these principles risks slowing down digital transformation and minimizing the benefits of a digital society. The ten key public policy principles are outlined below.

1. Look to Digital Progress as the Key Driver of Improved Quality of Life

Progress in a host of policy areas—including health care, transportation, energy, environment, public safety, and the economy—will be determined in part by how well nations develop and deploy IT. Solving surface transportation challenges, for example, will be difficult without the widespread use of IT, whether it is to implement congestion pricing or to provide real-time information on traffic conditions.

Policymakers in all nations should make spurring widespread use of IT a key component of public policy. Given the importance of IT to solving pressing societal problems, it is time that policymakers see IT issues not just as a narrow sideline but rather as a key component of public policy that supplements the government's three traditional tools of tax policy, government programs, and regulation. In other words, spurring digital progress should become the fourth leg of the government's stool.

Digital transformation must be put at the front and center of a wide array of public policy areas. IT transformation must become a key component not just of the commerce or telecommunications agencies but of every government agency or ministry. Government officials at all levels should lead by example by leveraging their own IT efforts to achieve more effective and productive public sector management and administration. In addition, they should focus on how their actions can drive digital progress generally in the broader society and economy.

2. Invest in Digital Progress

Many of the technologies and applications driving digital progress will be developed by the private sector and purchased by individuals, with little or no role needed for government. But many IT applications are inherently related to core public functions including transportation, education, health care, public safety, the provision of government services, community development, and the environment. These IT applications must be considered critical areas for increased public investment because they form core components of the new "intangible" public infrastructure that is driving improvements in quality of life. In addition, governments should be investing in research and development (R&D) and supporting private sector R&D to help develop new technologies and applications, including areas such as robotics, large-scale sensor networks, speech recognition and advanced computing.

3. Ensure Affordable and Widespread Digital Infrastructure

For the digital revolution to continue, policymakers must invest in renewing and revitalizing the underlying digital infrastructure. This entails not only spurring investment in physical IT infrastructure, but also ensuring that the appropriate and necessary regulations and standards exist to spur, and not hinder, adoption. Thus, for example, policymakers should make adequate spectrum available for wireless innovation by taking measures to open up unused "white spaces." In addition, policymakers must remain vigilant in ensuring that the components of our digital infrastructure, from global positioning system (GPS) signals to high-speed broadband Internet access, continue to be upgraded and improved.

4. Encourage Widespread Digital Literacy and Digital Technology Adoption

The benefits and promise of the digital information revolution are immense. As IT becomes more central to improvements in our lives, it will be important to ensure that the majority of citizens are digitally literate and have access to digital tools so that they can take full advantage of these benefits. In 2008, about 75 percent of American adults reported using the Internet;[1] the comparable percentage in many developing nations is lower. Internationally, there are multiple reasons why the Internet usage rate is not higher, including the affordability of Internet access, particularly for broadband telecommunications.[2] In developed nations, though, perhaps the most important factor why the Internet usage rate is not higher is a lack of digital literacy.

To succeed in today's economy people at least need basic computer and Internet skills. In the United States, some organizations, like One Economy, have taken steps to encourage digital adoption. And some states, like Kentucky and North Carolina, have stepped up efforts to expand digital literacy and IT and broadband takeup, especially in rural areas.[3] Around the world, various groups are working to improve digital access. Some companies, like Microsoft, have taken significant steps to help build digital literacy.[4] ITC, an Indian technology conglomerate, sponsors a program called "e-Choupal" to provide 6,500 Internet-connected computers in villages across nine Indian states.[5] But national governments need to do more in partnership with the for-profit, nonprofit, and state and local government sectors to spur digital literacy and takeup.

5. Do Not Let Concerns About Potential or Hypothetical Harms Derail or Slow Digital Progress

By definition, all technological innovation involves change and risk, and driving digital progress is no different. As we go forward in an array of areas, policymakers must give adequate concern to issues of privacy, security, civil liberties, and other related issues. But the focus should be on addressing these concerns where appropriate in ways that enable digital progress to rapidly proceed—not on stopping or slowing digital progress as so many advocacy groups and special interests try to do today. In part because of the claims made by some of these groups, and notwithstanding the progress that IT enables, all too often, well-intentioned policymakers are willing to consider laws and regulations that would slow digital transformation and reduce, not improve, quality of life.

6. Do Not Just Digitize Existing Problems; Use IT to Find New Solutions to Old Problems

IT offers powerful new methods for collecting, manipulating and distributing data; however, IT is a means and not an end. Simply using IT to continue existing practices will not necessarily lead to significantly better results. Thus, educators who merely use IT to replace classroom instruction with equivalent computer-based instruction and do not change their teaching methods, for example, may not see significant increases in students' learning outcomes; on the other hand, educators who use IT to change and improve their teaching methods may see impressive improvements in learning outcomes.

Organizations may find that investing in IT to solve targeted problems not only helps with the targeted problems but also gives them the tools they need to solve additional problems. City governments like Baltimore that collect citywide data, for example, can analyze this information in real time not just to improve deficient city services but also to discover new opportunities for government savings. Policymakers should recognize these benefits of IT, and promote the use of new solutions that harness IT to address existing problems in new ways.

7. Create Reusable Digital Content and Applications

Rather than focusing on creating flashy websites and graphics, government agencies and ministries should concentrate on creating reusable digital content using interoperable standards such as XML. Providing digital data that can be shared and reused multiplies its value many times—and is far more valuable than just building a website that may solve only a small set of problems.

Similarly, government-funded software applications should be developed to meet the needs of multiple users, such as other states or government agencies. One of the major benefits of software is that although the development costs can be high, the marginal costs of producing an extra copy are low. Governments should encourage local governments to create and share reusable applications rather than having each community build a new application on its own. For example, Canada initially developed AlphaRoute, an online adult literacy application, as a pilot project in Ontario, but now allows any publicly funded literacy and adult education center in the country to use it without charge.

8. Collaborate and Partner with the Private and Non-Profit Sectors

Policymakers should encourage collaborations between stakeholders in the public and private sectors. Government cannot provide its own digital solutions to every problem, nor will it always come up with the best solutions.[6] Instead, government should embrace opportunities to partner with the private and non-profit sectors. For example, in the United States, a number of public-private partnerships are working to spur demand for broadband services. One such partnership is ConnectKentucky which is helping to foster demand by providing a variety of services, including the No Child Left Offline project that provides computers and training to disadvantaged populations.

9. Lead by Example

When practical, government should be an early adopter of new technology rather than solely relying on industry to lead the way. Through technological leadership, government can play an important role in spurring markets and proving concepts. For example, government agencies can pursue green IT initiatives by establishing telework policies and creating telework best practices. Similarly, government could lead on promoting digital signatures for e-government applications.

10. Nudge Digital

Scholars have shown that using "choice architecture" institutions can encourage or discourage certain group behaviors, such as saving for retirement or eating healthy, by how the decisions are framed.[7] In fact, in a recent book on this subject, authors Thaler and Sunstein popularized the idea that government policy should "nudge" citizens towards good behaviors. Policymakers should recognize the power of this tool in shaping citizen behavior and design public policies that nudge citizens to more digital technologies.

As shown repeatedly throughout this report, digital solutions often provide substantial cost-savings and improve quality and outcomes. For example, imagine all of the savings in energy and paper if by default all personal banking and credit card statements were electronic. If citizens had to opt-out of programs, such as receiving electronic statements, instead of opting in, more individuals would participate. While exceptions still need to be made to provide fair and reasonable access to government services for all citizens, governments should make the default choice digital and not prevent private organizations from doing the same.

Endnotes

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2. Although it's true that lower income Americans are less likely to own a computer or be online, it is also true that the costs of owning a computer and having online service have fallen significantly over the last decade. It's now possible to purchase a very adequate computer with monitor—indeed one that just a few years ago would have been seen as a high-end consumer machine—for less than the cost of a 32-inch color (CRT) television. Moreover, is possible to get dialup Internet access for around $5 a month, with broadband costing more (DSL can cost as little as $15 a month).

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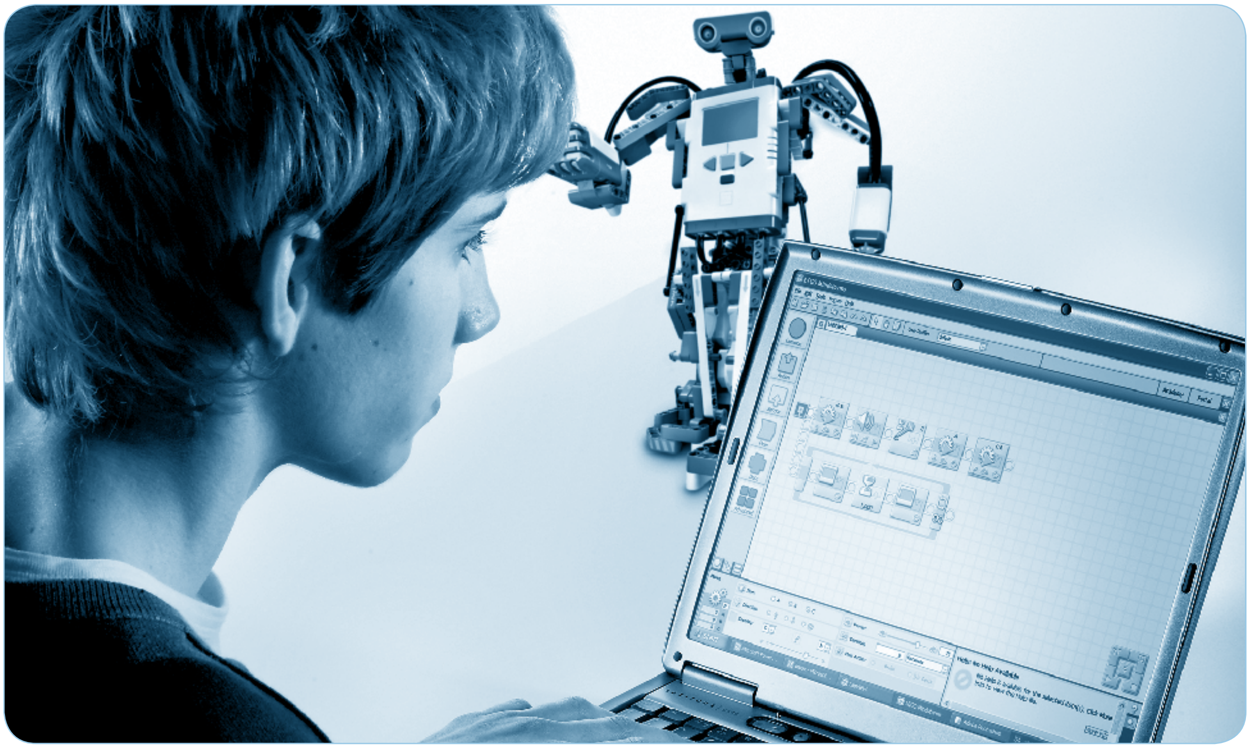
4. Education and Training



From the abacus to the slide rule to the computer, technology has always played an integral role in education—but information technology (IT) has now advanced to a point where it allows for fundamentally new and exciting improvements in the learning process. As discussed in this chapter, new online applications and tools have emerged with the potential to transform education by improving learning outcomes, serving multiple learning styles, and expanding access to education.

Learning software gives students instant feedback and individually tailors instruction in ways that a classroom teacher never could. Flexible online classes give people access to education that would never have been possible before the Internet. Parents now use the Internet to follow their child's school assignments and academic progress through Web portals. Companies use technology to save on workforce development costs. IT has made all of these and other innovative applications possible and promises to continue to rewrite the rules of what is possible in education and training.

It is one thing for a host of new e-learning applications and tools to emerge, but do they make a difference in the education of students? Advocates of IT in schools have long hailed the promise that IT can help reshape education, improving learning outcomes and student opportunities while saving money. With so much at stake, researchers have labored for years to determine the effectiveness of a variety of educational technologies—and their results are conflicting. The final section of this chapter reviews available studies and concludes that the effectiveness of using IT in the classroom will depend on the implementation, curriculum, and the pedagogical approach used by the teacher.

Improving Learning Outcomes and Serving Multiple Learning Styles

Perhaps the most important and widely cited IT-driven change in learning is in allowing individuals to learn more, both in the classroom and in the home. Though the history of educational technology is not a story of unqualified success in improving learning outcomes, the latest—and most sophisticated—applications of IT have been shown to yield results, while also helping to dramatically reshape the learning process.

Many IT applications and tools can make learning more effective for students. For the youngest students, preschoolers, IT is making toys more interactive and engaging. Today, many toys have integrated circuits in them to enable children to interact with them. Fisher-Price's Learning Phone, for example, helps teach babies and toddlers the alphabet using audio, an LED screen, and lighted buttons.[1] Fisher-Price also makes online games for babies and toddlers available free, including games that help toddlers learn letters, numbers, names of animals, sounds of musical instruments, and other things.[2] Additional technology toys include everything from LEGO Mindstorms, which let kids build and program real robots, to a handheld microscope that plugs directly into a TV to display magnified images.

For children at the K-12 level, a wide array of IT applications lets students learn more effectively. A host of new "intelligent" tutoring programs—like Carnegie Mellon University's "Cognitive Tutor," software—teach a variety of subjects at different levels, from foreign languages to physics. Research has shown that such tutoring programs can improve students' performance as much as one letter grade. The software may accomplish less than a human tutor can accomplish, but at $30 to $60 a student, the software is also significantly less expensive.[3]

Software and Internet applications give students access to new information and opportunities. The JASON Project, a nonprofit subsidiary of the National Geographic Society, connects students with great explorers and great events to inspire and motivate them to learn science. Its interactive website offers students the opportunity to follow along virtually with real scientists (via webcasts, interactive simulations, chat sessions, etc.) as they research, for example, the science behind megastorms.[4] Students participating in the JASON Project design experiments that use real cutting-edge scientific data. Research shows that simulation tools in science classes have the potential to help learners grasp more complex, higher order concepts.[5] An educational game called "Immune Attack," for example, is designed to engage students by battling virtual viruses inside a body while exploring concepts in immunology.[6]

New tutoring software allows students to proceed at their own pace. A software package used by the Success for All Foundation to assist tutors of first grade students with reading difficulties, for example, is "Alphie's Allie." For the student, this software program uses multimedia to represent concepts and sounds and provides continuous feedback on reading performance. For the tutor, the program suggests tutoring plans tailored to student performance, offers professional support and guidance for how to best undertake activities with the student, even including videos of expert tutoring techniques. Moreover, the software's level of involvement in the tutoring session is flexible, based on the needs of the tutor and the student. One evaluation found that students in a program that used “Alphie’s Allie” along with a multimedia program improved their reading by over a half a standard deviation compared to a control group.[7]

Games for children designed to double as learning tools have proliferated. Discover Babylon, for example, is a game that involves exploring the history of Mesopotamia to complete a series of challenges.[8] The Oregon Trail game teaches history and geography while engaging students in a set of tasks and challenges that expose them to pioneer life in the early 19th century in America. In addition, websites such as FunBrain.com offer children online games and activities that reinforce skills and subjects taught in schools. Many organizations also develop special “kid-friendly” websites that blend the line between education and entertainment. The U.S. Government Printing Office, for example, developed “Ben’s Guide to U.S. Government” to provide age-appropriate instruction, activities, and games to teach children about how the government works. Even the Nobel Foundation makes games available on its website to teach students about the work of different Nobel Laureates.[9]

Educators can find many useful resources on the Internet, too. The website Curriki, for example, provides a platform for educators to design and share curriculum that benefits students and teachers around the world. Similarly, websites like TeachingBooks.net provides teachers and parents learning guides and activities for popular children’s books as well as online videos of authors and illustrators of children’s books to encourage children to read. Other online resources, such as Enchanted Learning, use multimedia to engage children’s creativity to teach about nursery rhymes, inventors, music, and other subjects. TumbleReadables is a series of online books that allow children to read along with the story and get help with words that are difficult for them.

Perhaps the most important and widely cited IT-driven change in learning is in allowing individuals to learn more, both in the classroom and in the home.

Beyond helping students and teachers, IT is making it easier for parents to become and stay more involved in their children’s education. Innovative online programs like Edline can help parents to keep tabs on their child’s performance and academic progress in school. In a growing number of school districts, teachers use Edline’s Web portal to communicate with parents by posting homework assignments, test dates, and other relevant information.[10] Armed with a greater awareness of their child’s performance in school, parents can play a more central role in the learning process.

Recently, the deployment of fast broadband connections has been stimulating the use of the Internet for educational purposes. In 2005, for example, a quarter of all Danish Internet users in broadband households used the Internet for educational activities whereas only 14 percent of users in non-broadband households used it.[11] In the European Union, there is also a clear relationship between the percentage of teachers using IT in teaching and the percentage of schools with broadband connections.[12]

In a very powerful sense, IT offers the promise of fundamentally rethinking our current approach to education. For longer than any of us can remember, schools have been oriented around the traditional classroom, with a teacher leading a group of students through lessons and activities. This model owes its ascendance largely to expedience, not any pedagogical superiority. But the advent of advanced IT opens the door for alternative models. Advocates of “constructivist learning”—which “emphasizes active participation and reflection by learners, who should control the pace of instruction and construct knowledge by themselves”[13]—argue that IT can put the student at the center of the learning process, with the teacher facilitating each student’s tailored learning experience. Others have suggested harnessing technology in ways that actually inspire students to learn and conduct their own inquiries outside of the framework of traditional classes and standardized tests.[14] The key contribution of IT is that can allow the student's interests, needs, strengths, and weaknesses to drive the learning process, with the instructor facilitating rather than dictating.

When learning and teaching are done largely through teachers in the classroom, the ability to customize learning to the needs and abilities of individual students is limited. As a result, in traditional classrooms some students will struggle to keep up, while others will be bored and want to jump ahead. One of the benefits of IT is that it lets materials be designed much more around the needs of individual students.

Expanding Access to Education

Beyond offering greater choices to students in how they learn, IT offers greater choices to students in what they learn. Distance education, for example, expands the course catalogue for existing students, which has proven especially important in the K-12 context. Online learning gives a student at a small school in rural Idaho, for example, access to Chinese language or Advanced Placement courses her school does not offer. The power of this transformation should not be underestimated: As the online course catalog grows, it is conceivable that at some point in the near future every high school in the country will be able to offer students a course in every conceivable subject.

Such IT technologies are not just for youths; they are also helping adults learn. Corporate e-learning first became a major phenomenon about 10 years ago. Companies spent millions on software that moved teaching online, but the early products were too often ineffective, decidedly user-unfriendly, and simply boring. In the past decade, however, much has changed. In the past few years, firms have been successful with more sophisticated approaches, often blending tailored online learning sessions with classroom learning.[15] As a result, they are investing more in it. Among a sample of Fortune 500 companies and large public sector organizations, technology was used to deliver 37 percent of formal training in 2005, up from 24 percent in 2003.[16]

IBM's "Basic Blue" manager training program couples Web modules and simulation management exercises with classroom learning to achieve impressive efficiency gains: Studies have shown that the program costs one-third as much as a traditional classroom approach and managers learn five times the amount of material.[17] Recently, firms have begun to embrace a variety of new tools, including those that allow for peer-to-peer learning among coworkers. Indeed, blogs, wikis, podcasts, and collaborative software are becoming important tools for employees to exchange ideas and share insights.[18] IBM's WikiCentral, for example, has grown to include more than 12,000 users since its launch in 2005.[19]

Medical training has also begun to rely more on IT for various uses of e-learning. Medical students can now use high-fidelity simulators—lifelike robots that breathe, talk, and respond to treatments—to learn clinical and technical skills without the risk inherent in real-life patient encounters. These simulators enable students to practice and react to both common and rare events, and allow trainees to safely explore non-cognitive skills such as ethical decisionmaking, cultural awareness, and communication skills.[20] E-learning also enables faster and more efficient training for health care workers than is possible through traditional education methods. One example is a nurse training and certification program implemented in Kenya in 2005 to upgrade the skills of 22,000 enrolled nurses to registered nurses over five years. Enrolled nurses make up almost half of Kenya's health care workforce but lack many of the basic medical skills needed to treat critical diseases such as HIV/AIDS, malaria, and tuberculosis. Previously, a shortage of instructors and facilities meant that only a few hundred nurses could be trained every year. By developing computer-based

IT allows the student's interests, needs, strengths, and weaknesses to drive the learning process, with the instructor facilitating rather than dictating.

training modules that can be accessed from computers placed in hospitals throughout the country, Kenya has been able to rapidly address the country's critical nurse shortage.[21]

Recognizing that many workers do not relish spending their time undergoing corporate training, learning models often place a premium on holding a user's interest. As a result, simulators are gaining popularity. Enspire Learning, for example, offers an executive leadership training simulator aimed to achieve higher retention rates. In the computer simulation, teams of corporate executives compete to manage virtual companies by performing a series of tasks. Players are promoted or demoted based on their performance.[22] In another application of gaming, Quiznos sandwich shops have incorporated a "Sub Commander" game simulator into its blended learning program for its retail workers. In the game, trainees are challenged to apply their learning to constructing increasingly difficult sandwiches.

Moreover, online learning not only is effective but can be cheaper than in-person, classroom learning. Though the initial expenses of online learning programs can be high, companies save over time on course materials, employee travel, and instructor fees. As a result, the savings for online programs generally add up to about 50 percent. Caterpillar has managed to achieve even greater savings with its online training programs, which cost only one-third as much as classroom methods.[23] With online learning, IBM found in 2004 that it had saved $579 million over the last two years.[24]

IT is also reshaping how adults outside of organizations are learning. The growing phenomenon of online learning is one of the more important ways that technology is reinventing education. In online classes, educators deliver lectures or other educational content via Internet video or podcasts, which students with a broadband connection can often experience at a time of their own choosing. Some classes even take advantage of messaging software to incorporate discussions, either as asynchronous posts or real time discussion forums or chat rooms. And with the proliferation of institutions like the University of Phoenix, online learning is growing rapidly. In fact, more than 3.2 million students took online higher education courses in the fall of 2005—an increase of 35 percent over the previous year.[25]

Online education has become popular for a variety of reasons. First, distance learning powerfully expands educational opportunities for people who may be physically unable to attend an educational institution because they are busy with work or children, are disabled or incarcerated, or live in a rural area where the courses they want to take are unavailable. Indeed, research suggests that postsecondary students taking advantage of distance education are far more likely to be employed full time and taking classes part time than other students.[26] Mothers, in particular, have been drawn to online learning because of the flexibility it offers.[27] In order to accommodate both students and curricula with different requirements, there is no uniform model for online learning. Some courses are completely online, with no face-to-face contact between instructor and students, while other courses mix or supplement in-person sessions with online instruction.

In some cases, institutions offer online courses because online courses—especially those that can be scaled to serve many more students than could be served in a traditional classroom—are more efficient than traditional courses and can therefore cut costs. Online courses save classroom space, and the number of students in a class becomes less important when lectures are recorded as Web videos or podcasts. At the University of North Texas, for example, there are no caps on class size for online courses.[28] If an institution of higher learning can teach more basic introductory courses more efficiently, professors can as a result spend more time teaching the upper level courses that require more interactive class time.

In addition, online learning is not limited to the content available in formal classes. The Internet puts an unprecedented amount of information at one's fingertips. With an Internet connection and a healthy dose of self-motivation, anyone can learn about a range of topics. These include topics related to activities of daily living—for example, it takes only a few clicks to find a Web video demonstrating how one can reset a Palm Treo smartphone (of particular use to visual learners who might have trouble with owner's manuals). And they also include more academic learning opportunities such as "iTunes-U," Apple's clearinghouse for free lecture podcasts from leading universities. Other online learning programs target individuals in need of remedial learning. One such program is AlphaRoute, an online learning environment that helps boost adult literacy, which has been funded by the government of Ontario, Canada. The AlphaRoute program supplements online courses with discussion boards, live chats, and e-mail to foster interaction between students, instructors, and mentors. It includes special guidance for deaf students who can access online video to teach them American Sign Language.[24]

Student autonomy, though often an asset, can sometimes be a drawback to online learning. Autonomy allows for flexibility, but some students may lack motivation (as some studies have shown) or feel isolated if their only contact with instructors and other students is virtual. These concerns are serious and legitimate, and not all students are necessarily suited to learning in a virtual world. Still, distance education is moving in a direction that allows for greater interaction, minimizing such problems. New social software like Writeboard and InstaColl allow students to engage in virtual collaboration on group projects for which they can collectively write and revise documents over the Internet. Similarly, online classes are increasingly taking advantage of blogs, wikis, podcasts, and streaming media to increase collaboration and interaction between students.[30]

The Effectiveness of IT in Schools

Advocates of IT in schools have long hailed the promise that IT can help reshape education, improving learning outcomes and student opportunities while saving money. With schools spending $6.8 billion annually on instructional technology,[31] however, recent studies that call these claims into question have made the subject increasingly controversial. At a time when many schools are chronically underfunded, the question of whether computers are worth the investment is an important one.

Several recent overarching reviews have documented that teaching with technology in the classroom constitutes an improvement over traditional instruction. In a meta-analysis review of 20 studies of middle-school students, Pearson et al. (2005) found that technology has a positive effect on reading comprehension.[32] Waxman et al. (2003) concluded in a meta-analysis of 42 studies that technology had a small but significant positive effect on student learning.[33] Kulik (2003) examined a range of studies that evaluated technology programs for reading, writing, math, and science. Kulik found that several programs for math, science, writing, and particular kinds of reading software improve student outcomes.[34] In addition, various studies in Organization for Economic Cooperation and Development nations have found that Internet access can help make educational online activities more attractive and lead to improved educational performance.[35]

Not all academic studies have endorsed the view that IT improves students' educational outcomes. In 2004, for example, Rouse et al. evaluated a cutting-edge, scientifically based reading program for students with reading problems called *Fast ForWord*. This program is designed to "retrain the brain to process information more effectively through a group of computer games that slow and magnify the acoustic changes within normal speech."[36] Rouse et al. found in their randomized controlled evaluation that the program does not actually improve reading skills.

Fuchs and Woessmann's 2004 analysis of the relationship between the availability of computers and student learning, based on data from the Programme for International Student Assessment dataset from 32 mostly developed countries, found an inverse relationship between the availability of a computer at home and student achievement and no relationship between computer availability at school and student achievement.[37] But Fuchs and Woessmann's findings were convincingly refuted in 2005 by Bielefeldt. Bielefeldt observed that Fuchs and Woessmann's dataset is inadequate for drawing meaningful conclusions because the mere presence of computers does not tell us very much. He noted that the effectiveness of using computers will necessarily depend on implementation, curriculum, and the pedagogical approach of the teacher.[38]

In 2007, a highly publicized U.S. Department of Education report on a controlled study involving 9,424 students from three grades cast widespread doubt on the effectiveness of reading and mathematics software products in the classroom.[39] This study found no statistically significant difference between the performance of students in classrooms using 16 different reading and math software products and students in conventional classroom environments.

The Department of Education's assessment is certainly a chilling one for people hoping that IT will bring dramatically improved educational outcomes, but do its findings mean that spending on classroom technology is for naught? Not really. It is important to note that the study has several limitations, which may have affected its results.

First, the students using the reading and mathematics software products in question in the surveyed classrooms spent only between 40 and 50 hours using the products throughout the entire year—or about 15 minutes for each day of school instruction. For the overwhelming majority of their time at school, these students received exactly the sort of education as their counterparts in conventional classrooms, so it is no wonder they did not perform dramatically better. Indeed, a recent survey of computer usage in two districts—both with fewer students per instructional computer than the national average—found that students actually use computers for only about 2 percent of the possible time in a day. The authors concluded that "expecting to see substantial impact on students from the usage of any tool or strategy that is 'in play' only a few hours over a semester is probably unrealistic, no matter how powerful or important the tool might be."[40] Using computer technology for 15 minutes a day is a start, but the real power of IT will be unleashed only when we begin to fundamentally rethink the entire learning process in a way that maximizes its potential.

Second, learning outcomes are naturally tied to teaching pedagogy. Experts often speak of technology as "scaffolding" for learners, supporting them as they build their conceptual base. In this sense, technology is simply a tool of implementation, albeit a tool with powerful possibilities. A useful distinction can be drawn between so-called "Type I" educational technologies, which closely mirror the activities a teacher might have students perform; and the revolutionary potential of "Type II" educational technologies, which allow educators to radically reengineer teaching methods in "new and better ways" that would not otherwise be possible.[41] A Type I computerized reading program that closely mirrors the activities a teacher might have students perform probably will not achieve dramatically different results even if it makes learning easier, faster, or simpler. A Type II program, on the other hand, by allowing students to individually explore topics in ways best suited to each student's particular learning style or offering students instant feedback according to which future lessons and activities can be tailored, might achieve much better results. The Department of Education's study did test some award-winning software programs that incorporate Type II features (e.g., "Cognitive Tutor," which allows for tailored learning), but results for specific applications were not reported.

The effectiveness of using IT in the classroom depends on the implementation, curriculum, and the pedagogical approach used.

It is important to understand what so-called "technology immersion" does and does not do. Giving every student a laptop will not magically reinvent the learning process. A study of one such program in Texas schools found that teachers in classrooms with a laptop for every student still focused on imparting factual knowledge rather than in-depth concepts, while simply employing computers for similar tasks that students had formerly done with pen and paper.[42] Nonetheless, some studies show that the ubiquitous presence of computers can bring benefits, even when used in these traditional ways. Several studies show, for example, that student writing improves in such situations, likely because students engage in more written communication and use of word processing.[43]

What about the effectiveness of computers and the Internet at home? Although IT-enabled learning has benefits for all ages, most of the claims about computers in the home focus on children. Whether children who have access to computers and the Internet in the home gain an academic advantage over those who do not is a subject of debate. On one hand, using a computer to read webpages or engage in text-based communication requires users to exercise reading and writing skills, and many computer games for young users are designed to boost learning. On the other hand, if children use computers primarily for entertainment, there may be few benefits. As is the case for computers in schools, it is not the presence of computers but the way they are used.

Unfortunately, most of the studies that examine the issue of home computer ownership do not address the type of computer usage. Still, the results of most studies are positive. The best evidence of the importance of computers is documented by Jackson et al. (2004). They find that home Internet use for children between 10 and 18 improved performance on the standardized reading tests, likely because Internet usage depends so heavily on reading text.[44] In 2005, Fairlie concluded that, after controlling for family income, parental education and occupation as well as other factors, a home computer improves the chances that a teenager is enrolled in school.[45] Other recent studies have found a positive link between computer ownership and student performance,[46] and asserted that computer use during early childhood is related to cognitive development and school readiness.[47]

The results with regard to adult online learning are even more positive, although some higher education faculty members are skeptical of its benefits.[48] Nevertheless, the evidence indicates that in many cases online learning is as effective as a traditional classroom environment, while innovations in online learning continue to add more functions to the online classroom, promising to confer even greater benefits.

In 2001, in the most widely cited assessment of distance learning, Russell examined 355 studies and reports, concluding that there is "no significant difference" between online courses and traditional classrooms in terms of students' performance.[49] Subsequent reports have largely confirmed this finding. In 2004, Cavanaugh et al. published a meta-analysis of 14 scientifically based research studies of distance learning in K-12 classrooms, the conclusion of which was that students in online courses do not perform better or worse than their counterparts in traditional classrooms.[50] Another 2004 study of distance education at several academic levels found no significant difference,[51] while a 2006 meta-analysis of 25 comparative studies of distance education in allied health science programs found that distance education actually had a slightly positive effect on student performance.[52] In fact, a handful of studies have found that students in online classes at various levels perform better than traditional students, but the methodological rigor of several of these studies raises questions.[53]

In sum, the effectiveness of using IT in the classroom depends on the implementation, curriculum, and the pedagogical approach used. In school, at home, and at work, IT has the potential to make learning more effective, easier to access, and often more cost-effective. In all of these areas, IT is driving fundamental changes that promise to improve learning outcomes, and ultimately, improve our lives as a result.

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5. Health Care

From rural India to state-of-the-art hospitals in the United States, information technology (IT) is transforming and revolutionizing health care. Health care practitioners focus increasingly not just on doing something right but on doing the right thing—and doing the right thing in health care depends on the availability of good information.

In the future, many of the improvements in health care will come not from better drugs or better doctors, but from better managing information. Indeed, we are on the cusp of witnessing a radical transformation of health care as health care practitioners and patients increasingly embrace the IT tools of the digital age.

Already the effects of IT can be seen in the rise of new applications such as telemedicine and the growth of emerging fields such as bioinformatics. In fact, so much is happening that all the IT applications in health care—ranging from applications to streamline paperwork and business processes to extremely advanced clinical applications of IT to drive major medical innovations—are far too numerous to catalog.

As discussed below, IT is helping provide four key benefits in health care:

- reducing health care costs
- increasing access to health information
- improving the quality of health care
- increasing access to health care

Challenges to the adoption and use of health IT adoption, including economic barriers and interoperability issues, have slowed the digital transformation of the health care industry, particularly in the United States, but many of the benefits of health IT can already be found among early adopters.[1] Many health IT applications are still in the early stages of development where their benefits have been tested and proven but have not yet been scaled.

Efforts to quantify the benefits of emerging health IT applications are nascent. Researchers have tried to measure the success of health IT applications. But many researchers focus on only one metric of their success—such as user acceptance, economic benefits, usefulness, or improvement in patient safety—rather than conducting a comprehensive evaluation.[2] It is important to note that evaluative studies of health IT with negative findings may reflect an improper implementation of a technology rather than a problem with the technology itself. It is also important to recognize that case studies of health IT with positive findings may be difficult to generalize to a broader context. Even with these caveats, however, available research overwhelmingly points to a future where improvements in IT will continue to open new opportunities for advancements in health care.

Reducing Health Care Costs

As health care costs continue to rise, finding ways to stem the increases in health care costs while improving the quality are critical. And given that much of health care involves generating, processing, and transmitting information, it is not surprising that IT can play a key role in reducing costs.

Many early IT initiatives by hospitals reflected a naïve vision of how IT should be integrated into their workflow processes. In many cases, hospitals began developing IT systems without defining clear strategic goals and metrics for measuring performance.[3] Health IT systems are not simply "plug-and-play" products. To avoid wasting money and effort, hospitals must consider the extensive training, support, and workflow process development that need to accompany any investments in health IT.[4] Some hospitals have already wasted millions of dollars on health IT systems that failed to generate cost-saving benefits. The Cedars-Sinai Medical Center in the United States for example, spent $34 million to develop its own in-house computerized physician order entry (CPOE) systems system that ultimately had to be shelved after a few months of use because clinicians found too cumbersome.[5]

Although the potential financial benefits of IT in health care have not been realized on a large scale to date, a growing body of evidence suggests that IT will introduce substantial cost savings in health care, which ultimately will be passed on to patients. Estimates of the overall cost savings vary, but most studies show the benefits of health IT greatly exceed the costs. Societal cost savings from implementing and using health IT in the United States, for example, have been estimated by two studies at approximately $80 billion per year.[6] Studies of European countries

Cost savings from implementing and using health IT in the United States have been estimated by two studies at approximately $80 billion per year.

echo the claims from U.S. studies that the cumulative benefits of IT projects in health care will far exceed the costs.[7]

Cost savings from health IT identified by researchers come from an array of sources, most related to using information more effectively. Much of the savings in available estimates comes from increases in efficiency, such as shorter hospital stays because of better coordination, better productivity for nurses, and more efficient drug utilization.[8] In particular, researchers expect investments in electronic health records (EHRs) to generate substantial savings. EHRs contain a patient's complete medical history, including a full listing of the patient's illnesses, treatments, laboratory tests, drugs administered, and allergies. EHRs provide doctors with more complete information about their patients, which reduces the need for duplicative and unnecessary medical tests.

Hospitals can save money by using IT-enabled operational decision support systems to analyze clinical and financial information, including resource utilization levels, component costs, and clinician performance.[9] Operational decision support systems that support administrative decisionmaking can help to ensure higher levels of efficiency and improved business processes.[10] In addition, some hospitals are implementing self-service kiosks and online portals to automate certain functions such as patient registration and payment, thereby reducing wait times and decreasing staff utilization.[11]

Another source of cost savings from health IT is electronic claims processing. In 2006, 75 percent of claims submitted by medical practices in the United States were received electronically, compared with 44 percent in 2002.[12] Electronic claims processing results in greater efficiency and lower costs.[13] The successful transition from paper-based claims processing to electronic claims processing illustrates the potential for improving other health care business processes.

Increasing Access to Health Information

Ever since Hippocrates developed an oath for doctors, the model of health care has been one where the doctor had the information and the patient received it. But this model was always flawed because it failed to make patients active participants in their care and treatment. One reason that some individuals are not more actively involved in managing their own health and health care is that they have bought into the idea of the doctor as the expert, believing that "the doctor always knows best."

Now IT is fostering a radical transformation of health care by enabling patients to be much more empowered, both about the kinds of treatments that are available to them and about the quality of the health care providers they choose. By providing patients with access to more and better information, IT empowers them to make more informed health care decisions. By increasing patients' access to their own medical records and to a plethora of information to help patients make better decisions, IT has the potential to improve health care.

When patients have access to their personal medical records, they can take a more active role in their health care and routinely monitor their symptoms and treatment. Access to personal health records helps give patients a stronger sense that they have control of and responsibility for their own care. Many online applications, including WebMD, Revolution Health, and Microsoft HealthVault, have emerged to allow individuals to track and analyze their personal health information.

With online access to their personal health record and new Web-based tools, individuals can manage their health information online as easily as they manage their finances. Currently, for example, online applications allow patients to track health markers such as their blood pressure, cholesterol, and body mass index to see how these indicators changes over time and how they compare to healthy patients of the same age and sex. Patients can combine these online tools with medical home monitoring devices to track and compare their health between office visits.

Consumer demand for EHRs and personal health records is growing, and many people have embraced the technology when it is available. One of the leading EHR software companies reports that its product is used by more than 58 million people, mostly in large multispecialty practices.[14] Usage varies by country: In the United States, approximately 28 percent of primary care physicians have EHRs versus

79 percent in Australia, 89 percent in the United Kingdom, and 98 percent in the Netherlands.[15]

In the United States, Kaiser Permanente, the largest not-for-profit health plan in the country, has implemented an EHR system called KP HealthConnect, which allows patients and providers instant access to their medical information. Physicians use the system to place orders, review laboratory results, and access their patients' medical histories. Health plan members access the information using a secure Web portal that allows them to review laboratory results and office visits, as well as to communicate with their providers. As of mid-2007, 1.4 million Kaiser Permanente members had signed up for online access.[16] Kaiser Permanente has also partnered with Microsoft to allow its members to voluntarily manage their personal health records using Microsoft HealthVault.

Some health systems that have introduced EHRs have found that they helped reduce health care costs associated with visits to physicians. One study found that after introducing EHRs, Kaiser Permanente reduced visits to primary and specialist outpatient care by 5 to 9 percent.[17] Another study found that annual adult primary care visits decreased between 7 to 10 percent among patients who communicated with their providers electronically.[18] Secure Web portals also automate and simplify many health care transactions for the patient, including booking doctors' appointments, making copayments, filing for insurance reimbursements, and ordering prescription refills.

In addition to EHRs and personal health records, other IT tools also increase access to health information. Today, patients use health resources on the Internet to learn more about medical conditions, treatments, and prevention. Indeed, a survey in 2005 found that 80 percent of U.S. Internet users have looked for health information online.[19] Online health resources eliminate barriers to information by giving patients more convenience and privacy, access to online social networks, and the ability to communicate with specialists around the world.

In the United States, for example, the National Library of Medicine has indexed over 16 million health articles in PubMed (a free search engine of medical and life science journals) and maintains MEDLINE (a database of publicly available medical information).[20] These tools provide doctors and patients with access to the latest research from clinical studies, information on new medicines and treatments and explanations of illnesses and diseases. In a world where new health research is released daily, it is difficult for doctors to keep up with the latest findings. By giving patients access to the latest health research, the Internet enables patients to find information that often their own doctors are not aware of. This is one reason why multiple studies have found that Internet-based patient education is both useful and effective.[21]

By unleashing the power of information, health IT enables individuals not only to learn about medical conditions and treatments but also to obtain information about the quality of care from different health care providers. One of the realities of the health care system is that the quality of care between doctors and hospitals can vary widely and patients suffer for it. Yet, until recently, patients had few resources for distinguishing between different quality doctors. Most relied on imprecise indicators such as word of mouth or the name of the school on the doctor's diploma.

Now IT is enabling health care consumers to make more informed decisions about where they seek treatment. Tools available to help consumers make such decisions include public and nonprofit projects such as the U.S. Department of Health and Human Services' Hospital Quality Initiative[22] and the Leapfrog Group's hospital ratings.[23] Patients can now use these tools to receive objective performance metrics by which they can compare hospitals in their community. Thus, for example, patients can learn which hospitals in their community received the highest ratings on patient safety or have the most experience and positive outcomes with a particular high-risk treatment.

Improving Quality of Care

Three important ways in which the quality of health care can be improved are by (1) reducing the number of medical errors; (2) improving our understanding of the effectiveness of health care interventions; and (3) introducing new, more effective diagnostic and treatment interventions. As discussed below, IT is playing a key role in all three.

Fewer Medical Errors

Most health care errors stem from limited or mistaken information. A drug is given to the wrong person. A pharmacist misreads the dose on the prescription and dispenses the wrong dose. A doctor does not know the most accurate medical tests for a patient. Health IT can reduce these and a host of other kinds of medical errors, thus increasing patient safety.

Health IT can help reduce medical errors by providing accurate information when it is needed. Medical practices, for example, can improve patient safety by using computerized physician order entry (CPOE) to eliminate the ambiguity of hand-written medical orders. To provide additional improvements in the quality of care, CPOE can be used in conjunction with clinical decision support systems (CDSS). These systems, which include automated diagnostic programs, computerized test result interpretations, and drug management systems, provide health care workers with real-time information to aid with treatment and reduce medical errors.[24] CDSS can provide expert medical guidance to doctors to help ensure that they follow protocol and adhere to medical best practices.

Investments in health IT applications such as CDSS also have the potential to improve care and reduce costs by increasing patient safety. Adverse drug events account for 19 percent of injuries in hospitalized patients in the United States and cost hospitals alone over $2 billion per year, not including malpractice costs or the costs of injuries to patients.[25] One study found that health IT could eliminate around 200,000 adverse drug events in the United States at a national savings of $1 billion annually.[26]

Medical practices have also found various uses of radio-frequency identification (RFID) technology to improve efficiency and patient safety. RFID allows the automatic identification of objects through the use of wireless RFID tags or transponders. Thus, for example, hospitals can use RFID to track and monitor patients and manage items in the supply chain. RFID helps hospitals achieve positive identification, thereby increasing patient safety. Health care providers can use RFID to automatically verify that the right patient receives the right drug at the right dose at the right time.[27]

One reason why doctors have relied on paper records is that they need to be able to carry patients' records from one room to another, from one facility to another. But now portable IT devices such as tablet PCs, handheld computers, or personal digital assistants (PDAs) can provide physicians and nurses access to more complete and accurate electronic health information at the point of care. Thus, for example, doctors can use PDAs to order and check lab tests, take notes, and electronically prescribe medication. In addition, health care providers can use portable IT devices to get quick access to medical reference information such as medical literature and pharmacopoeias, or drug information databases. Rapid access to information is especially important in the critical care environment, where providers can use their portable IT devices to look up information such as drug dosing.[28]

Health care providers can use RFID to automatically verify that the right patient receives the right drug at the right dose at the right time.

Improved Understanding of the Effectiveness of Health Interventions

IT can equip health care providers with new strategies and methods for preventing, diagnosing, and treating medical conditions. More generally, health IT can help improve medical care by making it easier for doctors to provide evidence-based medicine. Evidence-based medicine is the use of treatments judged to be the best practice for a certain population on the basis of scientific evidence of expected benefits and risks. Evidence-based medicine requires health care providers to have sufficient knowledge of both the patient and the scientific evidence to make informed decisions.[29]

IT is providing that information by digitizing health information to provide doctors with instant access to their patients' complete medical history and the latest medical research. One reason why health care is not as effective as it could be is that the relationship between medical interventions and patient outcomes is unclear. Information about efficacy is derived largely from clinical trials, which are by nature limited in scope and coverage. Doctors need not only information about what works in a clinical trial but also information about the effectiveness of various treatments in real-world settings with specific types of patients.

As medical research becomes digital, health researchers will be able to use data mining techniques for medical research. Thus, for example, doctors will be able to review the risks and benefits of a specific drug or medical procedure, not just based on clinical trials, but based on a population sample that matches the profile (age, sex, body mass index, etc.) of their patient. In addition, health care providers will be able to use rapid learning networks to spot dangerous side-effects from drugs or other treatments, as well as identify effective treatments more rapidly.[30] These rapid learning systems will also greatly increase the knowledge base for evidence-based care.

In the future, public health officials will also be able to use IT to more effectively detect outbreaks of infectious diseases and monitor treatment efforts. Already researchers have used increases in computing power to study various pandemic models. Thus, for instance, scientists have been able to evaluate the effectiveness of different public health strategies to respond to the outbreak of a worldwide influenza pandemic.[31] At the U.S. Department of Defense, the Electronic Surveillance System of Early Notification of Community-based Epidemics (ESSENCE) collects health data in real time from more than 400 facilities around the world and helps medical teams identify early-warning indicators of a possible disease outbreak, even if the system cannot identify the disease.[32] As medical research becomes increasingly data-intensive, IT will play an even greater role in storing, transmitting, and processing medical data.

Health care providers will be able to use rapid learning networks to spot dangerous side-effects from drugs or other treatments, as well as identify effective treatments more rapidly.

New and Better Methods of Diagnosis and Treatment

IT is playing a key role in introducing new, more effective diagnostic and treatment interventions. As described below, researchers have developed or are developing IT-enabled medical devices that can be used to perform sophisticated diagnostic tests outside a doctor's office; IT-enabled prosthetic and orthotic devices far more sophisticated than any used in the past; IT-enabled "smart" implants that permit doctors to monitor and treat patients remotely; robotic surgical techniques; and many other technologies that improve diagnosis and treatment. Advances in IT and bioinformatics also enable the processing and storage of vast amounts of biological data.

Given that integrated circuits are in everything from cars to cell phones, it should come as no surprise that they are increasingly part of all types of medical devices. IT-enabled medical devices that have been developed or are being developed include portable devices that can be used outside the doctor's office. BrainScope, for example, is a portable medical device developed by researchers to measure brain electrical activity to diagnose concussions from head trauma. Although traumatic brain injuries are common, emergency workers have few tools with which to assess the severity of the injury. Portable devices such as BrainScope can aid emergency workers in performing triage.[33]

Researchers are also working to miniaturize existing medical devices such as electrocardiographs (ECGs) and sonographs to make them more portable. A compact ECG to enable doctors to bring the device to their patients, for example, has been developed by General Electric. Previous ECGs weighed around 15 pounds and cost $10,000, but by reengineering the ECG with low-cost materials and off-the-shelf electronics, engineers were able to shrink the device to less than 3 pounds and only $1,500. In rural India, this level of portability means that doctors can carry the compact ECG device with them as they travel from village to village, thereby ensuring that all patients receive better care.[34]

One of the most amazing uses of IT in medical devices is in increasingly sophisticated prosthetic and orthotic medical devices. A wide range of prostheses from artificial limbs to cochlear implants that allow hearing have emerged because of a combination of factors including faster low-power processors, improved biosensors, and a better understanding of the human brain.[35] Scientists have even designed an artificial silicon retina (ASR) microchip to restore lost vision. In one pilot project, scientists designed and implanted a 2-mm-diameter ASR microchip that used electrical stimulation to simulate how light would affect certain membranes; perhaps even more impressive, this microchip is powered entirely by incident light.[36] By restoring or improving their vision, this technology has dramatically affected the lives of individuals afflicted with blindness or visual impairments.

Although the bionic man was once something seen on a 1970s science fiction TV show, a wide array of IT-enabled advances in robotics has led to unprecedented advances in artificial limbs and orthoses, bringing the fantasy of creating a bionic man or woman closer to reality. Exoskeletal orthoses, or wearable robots, have been developed that provide adaptive robotic assistance to stroke survivors with weak muscles. These devices help stroke survivors relearn muscle control through therapeutic exercise. Patients control these devices though noninvasive electromyography biosensors that measure the electrical potential of muscle activity.[37] Many patients find that controlling these exoskeletal devices is intuitive, but such devices must piggyback on existing muscle groups and nerve signals rather than using brain activity.

As researchers continue to develop faster and more accurate brain-computer interfaces, patients may eventually be able to directly control a prosthesis with their brain.[38] Doing so should give patients more control over their artificial limbs and enable additional patients to benefit from this research. Already scientists have succeeded in training monkeys with electrodes implanted in their motor cortex to move a robotic arm to feed themselves using only their brains.[39] In addition, scientists have begun to develop methods to recreate the lost sensations in paraplegics and amputees by providing these patients with sensory feedback. Currently, most patients must use visual feedback to operate their artificial limbs. The goal is to develop prostheses that provide biofeedback by, for example, sending heat signals if temperature sensors indicate that an object is hot.

IT is also bringing us closer to another science fiction vision we saw in the 1960s in the Raquel Welch film “Fantastic Voyage.” Rather than miniaturizing people in a submarine to travel inside a patient’s body, however, IT is enabling a host of miniature implantable devices to do the same job. Advances in embedded systems, or special-purpose computers with a single task, have led to the development of microelectromechanical systems (MEMS) that integrate mechanical elements, sensors, and electronics on a silicon substrate. MEMS enable the development of “smart” implantable medical devices that allow health care providers to monitor or treat patients remotely and with minimal imposition on the patient.

Currently, for example, implantable medical devices that permit continuous monitoring of glucose levels in patients with diabetes are marketed by several companies. The traditional approach to monitoring diabetic patients’ blood glucose levels, using finger sticks, provides only a few data points. Continuous monitoring allows both patients and doctors to track diabetic patients’ glycemic patterns over time and also helps patients better understand the effect of certain behaviors on their glucose level.[40] Health care providers can also use implantable medical devices to deliver drugs that might otherwise require a trip to the doctor’s office.[41]

Even the brain is not off limits for IT-enabled medical implants. Doctors are using brain implants that provide deep brain stimulation to treat medical conditions such as Parkinson’s disease, Tourette’s syndrome, depression, and obsessive-compulsive disorder. These devices monitor brain activity and help the patient by sending or blocking electrical activity in the brain.[42]

Other microelectronics used in health care include a pill-sized, ingestible thermometer that can monitor the body’s core temperature and wirelessly transfer the readings to a nearby computer. Developed by the National Aeronautics and Space Administration (NASA) for astronauts and now used by athletes, firefighters, and divers, the ingestible thermometer provides an effective mechanism to continuously monitor the core body temperature of individuals exposed to extreme heat or cold.[43] Similarly, engineers have developed a pill-sized camera that patients can swallow to view their digestive tract and eliminate the need for a more intensive endoscopy which requires sedation.[44]

When Wilhelm Conrad Röntgen discovered X-rays in 1895 he could not have imagined the transformation in health care that this discovery would bring about. Medical imaging is now a widely used diagnostic tool for anything from colon cancer to pneumonia. In addition to using traditional film-based X-rays, health care providers now use a variety of newer forms of medical imaging such as digital X-rays, computed tomography (CT) scans, magnetic resonance imaging (MRI), positron emission tomography (PET), and photoacoustic imaging. Some forms of medical imaging are more advanced than others. CT scans, for example, use computers to compose a high-resolution cross-sectional view of an area of the body from multiple images that traditional X-ray methods cannot provide.

Advances in IT have led to advances in medical imaging techniques that let health care providers see into the body in much more accurate and detailed ways. Although the underlying technology for many of these medical imaging techniques has not changed, recent advances in IT have introduced a number of benefits. Thus, for example, patients using an EHR benefit from digital images as they can easily access, store, and share their lifetime history of medical scans with any of their health care providers.

Other benefits of IT can be seen in areas such as digital mammography. Digital mammograms use the same X-ray science as older mammograms, but using a digital receiver in lieu of film yields a number of benefits, including less radiation exposure for the patient, immediate lab results, and most importantly, more accurate readings. In addition, electronic storage and transmission of mammograms allows doctors to easily compare mammograms from multiple years or patients to provide more accurate diagnosis.[45] The European MammoGrid project created a European-wide geographically distributed database of digital mammograms, which allowed radiologists to make comparative diagnoses with other images from the databases.[46] Breast cancer is the second most common form of cancer in the world, and IT-enabled advances such as these ensure that more accurate screening for the condition helps save lives.

Another advantage of digital images is that they can be analyzed and manipulated by computers after processing. Projects such as the Visible Human Project, for example, have created detailed, three-dimensional representations of the human body.[47] In addition, researchers have used medical imaging to develop virtual reality animations of the human body.[48] These virtual reality experiences enable researchers and students to better visualize different human systems. Researchers also can model diseases in these virtual environments and help improve research on better treatments.

Advances in the fields of medical imaging and robotics have even enabled computer-assisted surgery. The da Vinci Surgical System, for example, allows surgeons to use a robotic eye and robotic arms to conduct minimally invasive surgeries such as removing the gall-bladder, removing the prostate, and conducting other various surgical procedures on the chest. Surgeons control the da Vinci Surgical System through a special console that gives them an enhanced view of the operating table and precise control of the electronically controlled medical instruments. By allowing surgeons to make only small incisions, computer-assisted surgery reduces patients' postoperative scarring and pain and improves patients' recovery time and safety.[49]

Computer-assisted surgery has also led to the development of telesurgery. Using high-speed networks to transmit real-time audio, video, and health data, surgeons can remotely operate robotic arms in an operating room thousands of miles away. The first transatlantic surgery occurred in 2001, with the surgeon in New York City and the patient in Strasbourg, France. Telesurgery has the potential to improve care for residents in rural locations by providing them access to the best medical experts. Telesurgery can also be used by patients too sick to travel or in locations without a doctor, such as a war zone or the International Space Station.[50]

A special form of computer-assisted surgery uses a visualization technique called Augmented

Reality, which supplements the real world with three-dimensional virtual objects that appear to coexist in the same space as the real world in order to enhance the user's perception of and interaction with the real world. The use of a head-mounted display that enhances the sense of sight by combining virtual objects with real-world objects is the most common example of this technique.[51] In medicine, Augmented Reality has a variety of applications. By providing surgeons with virtual X-ray vision, for example, Augmented Reality can allow minimally invasive or noninvasive surgery. Minimally invasive surgery is more difficult than traditional surgery (because small incisions reduce the ability of a surgeon to see inside), but it reduces trauma to the patient and shortens recovery times.[52]

Augmented Reality can also be combined with traditional vision to give physicians a better understanding of the patient. A surgeon could create a three-dimensional model of a tumor from ultrasound images, for example, and then superimpose the tumor model onto real-time images of a patient. This technique would allow the surgeon to perceive the exact position of the tumor in the patient's body and make better decisions regarding treatment.[53] It would also allow a doctor to conduct a needle biopsy of a breast tumor, for example, using Augmented Reality to visually guide the needle.[54]

IT is enabling researchers to develop more advanced pharmaceutical treatments. In particular, researchers have looked to grid computing as health care research becomes more data and processor intensive. By distributing storage, data analysis, and data processing across a grid, grid computing enables participants to build better, more advanced, system together than they would have been able to build alone. Traditionally, health researchers conduct *in vivo or in vitro* studies—medical studies using either living organisms or test tubes. But grid computing has opened up the possibility of in silico studies, or medical studies conducted by computer simulations. Using grid computing, a researcher may conduct a simulation to evaluate which drug or combination of drugs will likely be most effective on a patient given a set of genetic markers. These simulations require vast amounts of computing power to analyze not only large data sets but also drug interactions, drug resistance, immune responses, and mutations.[55]

One of the most successful examples of grid computing in health care is the cancer Biomedical Information Grid (caBIG).[56] This initiative, overseen by the U.S. National Cancer Institute, is the result of a collaborative effort by health care researchers to build an flexible, online platform for cancer research. The caBIG infrastructure consists of multiple tools, applications, and data repositories that facilitates research, encourages collaboration, and makes data from disparate sources more accessible. Applications include a clinical trial case management system, an *in vivo* imaging system, tissue banks and pathology tools, and numerous biomedical data analysis tools. The caBIG infrastructure helps researchers generate and validate hypotheses, record and share valuable research results, and speed the transition of research findings into clinical practice to help cancer patients.[57]

Finally, it should be noted that the most important medical breakthrough of our era—the unlocking of the human genome—would not have been possible without IT, in particular, the enormous processing power found in today's supercomputers. The Human Genome Project sought to correctly analyze and sequence the 3 billion chemical base pairs that make up human DNA. Traditionally, biologists use a technique known as chain termination for DNA sequencing. The problem with this method is that it allows only short strands of DNA to be sequenced. The process of sequencing each strand in order proved to be too slow for sequencing the entire human genome. For that reason, researchers devised a

Using high-speed networks to transmit real-time audio, video, and health data, surgeons can remotely operate robotic arms in an operating room thousands of miles away.

new technique known as whole genome shotgun sequencing in which they segmented DNA into small, random fragments, and then used a network of computers operating in parallel to reassemble these fragments into the correct sequence.[58] Further research in genetics will rely on advances in IT and bioinformatics to successfully store, manage, and analyze biological data.

Telemedicine systems can also be used to provide access to health care for individuals in remote locations who would otherwise not receive care.

Currently, one of the biggest challenges for researchers is to better understand proteins, the organic compounds responsible for many of the essential functions in cells. Understanding proteins will help researchers fight diseases such as HIV/AIDS, malaria, cancer, and Alzheimer's disease. It is important to understand the three-dimensional structure of a protein because the shape of a protein determines how it interacts with other molecules. Although scientists can find the sequence of amino acids that constitute a particular protein, predicting the shape of the protein requires testing an enormous number of possibilities to discover which structure is most stable.

Yet solving the problem by computer still presents an enormous opportunity over the more costly alternative of discovering protein structures in the lab. To help speed this process, researchers at the University of Washington created the Rosetta@home project—a distributed computing project that allows Internet users donate their spare computer processing power to help with this research.[59] As of May 2008, the project had over half a million computers working on the project at any given moment.[60] However, the research team realized that while the computers were making important progress, human problem-solving skills and intuition might help find the solutions faster. In response, they developed Foldit, an online, multiplayer game that allows Internet users to compete against each other to find the best protein structure. Future plans include allowing participants to design new proteins that might treat or prevent diseases.[61]

Increasing Access to Health Care

If you want access to the best health care in the world, you should live close to a major world-class research hospital, usually located in an urban area. Right now, if you do not live near such a facility, you may not get the best treatment. The good news, though, is that IT is helping to break down geographical barriers to health care by enabling patients to have access to top-quality care without necessarily being physically close to it.

Hospital and Other Applications of Telemedicine

Recent advances in IT that enable large amounts of data to be quickly transferred anywhere in the world have give rise to telemedicine—an application of clinical medicine where medical information is transferred via telephone, the Internet, or other networks for the purpose of consulting and sometimes performing remote medical procedures or examinations. Telemedicine allows patients to have access to medical experts even when they are geographically separated from them.

Some applications of telemedicine offer patients benefits including more convenient care, better access to specialists, and an alternative to office visits for patients with minor medical questions. One application called Cisco HealthPresence, for example, uses the network as a platform that allows patients and doctors to interact over a secure connection through high-definition audio and video; it also allows doctors to obtain vital signs and diagnostic information from their patients using special network-enabled medical devices.[62] To take advantage of this service, patients visit a Cisco HealthPresence pod staffed by an attendant who assists with the technology and ensures the cleanliness of the pod.

Telemedicine systems can also be used to provide access to health care for individuals in remote or other locations who would otherwise not receive care.

In Australia, for example, the Broadband for Health Program connected indigenous and rural communities with health care providers in urban areas. In the United States, telemedicine systems have also been used to bring access to low-income residents in urban areas of the United States. Fort Wayne, Indiana, which has an extensive fiber-optic broadband system deployed by Verizon, for example, has set up a system where retired nurses help provide health evaluations for low-income residents without health insurance through means of two-way broadband connections.[63]

The conversion of health images into digital forms that can be sent over telecommunications networks has allowed the development of another application of telemedicine known as teleradiology. Teleradiology is the electronic transmission of radiological patient images such as X-rays, CTs, or MRIs from one location to another for interpretation and consultation. In 2003, two-thirds of all radiology practices in the United States reported using teleradiology.[64] Medical practices use teleradiology to transmit medical images electronically to radiologists located in another region or country, at home or simply another wing of the hospital. Teleradiology may also be used to send medical images to a specialist or provide a second opinion. Benefits from teleradiology include better quality radiology in small and rural hospitals and faster turnaround on interpretations.[65]

Some hospitals have used telemedicine to improve care for critically ill patients via remote electronic intensive care units (eICUs). The provision of around-the-clock care to critically ill patients in ICUs by physicians who specialize in their care (intensivists) is considered key to improving outcomes for such patients, but some hospitals cannot provide such care because of a shortage of intensivists. Remote eICUs address this challenge by allowing a team of intensivists to monitor critically ill patients in the hospital continuously using streaming video, EHRs, and remote sensors, so that they can coordinate care with the physicians and nurses who are caring for these patients in the hospital. A health system in Kansas City implemented an eICU to leverage its limited intensivists and standardize clinical practices and processes in its seven hospitals. Researchers found that this initiative reduced the health system's ICU and hospital mortality rates.[66] In addition, it reduced patients' ICU and hospital length of stay, a factor that strongly influences hospital costs.[67] A study of the first major eICU installation similarly found that the hospital reduced

Box 5-1: Per Capita Investments in Health IT by the United States and Other Countries

Investment in health IT varies by country, but overall government investment in health IT in the United States significantly trails many European countries. As shown in the table below, total per capita investment in health IT by the federal government in 2005 was only $0.43 per capita in the United States versus an astounding $192.79 per capita in the United Kingdom. Yet the United States spends more on health care than any other nation, with health expenditures reaching $2.0 trillion per year.[68]

Total government investment per capita[69]
(as of 2005)

United States	$0.43
Australia	$4.93
Canada	$31.85
Germany	$21.20
Norway	$11.43
United Kingdom	$192.79

While these numbers demonstrate the disparity between investments in health IT among different countries exact comparisons are never perfect because of differences in each country's health care system. For example, investments in electronic claims processing for health services may be included in the figures for some countries, such as the Canada which has a single-payer health system, but not others.

One reason for the relatively low investment in health IT in the United States is that while most private medical practices bear the cost of implementation, many of the benefits of these systems are received by the insurance companies and the patients. Although most researchers agree that investing in health IT yields a net societal benefit, the implementer does not always receive all of the benefits. It is not surprising then that single-payer systems, such as the United Kingdom, have much higher levels of investment in health IT.

mortality by 27 percent and reduced the costs per ICU case by 25 percent.[70]

Mobile devices are rapidly becoming an important platform for health care, as well. In 2007, for example, a Gartner study reported a worldwide total of 3.3 billion mobile connections from portable devices such as handheld computers and cell phones.[71] As a platform for health care, mobile devices have a number of benefits including low cost and widespread usage, even in underdeveloped regions. In addition, mobile devices can provide quick access to expert care even in remote or rural locations. Because of these advantages, researchers have begun developing health care applications for patients and providers using mobile devices as a platform.[72] Currently, for example, health care workers can use text messaging on cell phones as a tool to educate patients about diseases and send them medical alerts. In one study, health care workers experimented with an 11-week protocol to educate parents of children with type 1 diabetes using the mobile phone short message service (SMS) and received high user satisfaction.[73]

Many new applications of telemedicine are on the horizon. Recently, for example, researchers have begun developing a virtual speech therapist to help the estimated 40,000 people who suffer from a stroke every year in Malaysia. This application will address both the shortage of speech therapists in Malaysia and the difficulty patients face with traveling to therapy centers.[74] Other applications of telemedicine may make use of sensor networks and portable global positioning systems (GPS) to report personalized medical hazards to patients. Thus, for example, asthmatic patients may carry a GPS-enabled mobile device that can alert the patient when the ambient air quality reaches dangerous levels from allergens or pollutants.[75]

Remote Monitoring of Patients with Chronic Conditions

Health care providers use remote health monitoring of patients with chronic conditions to identify potential problems and recommend preventive treatment. Medtronic, for example, currently produces a number of implantable cardiac resynchronization therapy and defibrillator (CRT-D) devices that support remote monitoring.[76] Using a wireless data reader that connects to standard telephones, patients can securely transmit the medical data recorded by these medical devices to their health care provider. Their physicians can then review the patients' health information remotely, thereby reducing the number of office visits, a major benefit for patients with chronic diseases or who need frequent care.[77] Similarly, obstetricians can remotely monitor the blood pressure and fetal heart beat of their patients at home, rather than requiring the patients to be admitted to the hospital.[78]

The Renaissance Computing Institute in North Carolina has developed an Outpatient Health Monitoring Systems (OHMS) for patients with chronic conditions such as asthma. The OHMS uses multiple wireless sensors to monitor both a patient's condition and environmental factors that might affect that condition (such as pollution, allergens, temperature and humidity). Using an OHMS, patients can work with their doctors to more effectively manage their health before health crises arise.[79]

Remote monitoring gives patients with chronic conditions more flexibility to travel because their physicians can access their health information when the patients are away from home. In addition to convenience, home monitoring can lead to better quality care. A pilot project in Boston, for example, provided diabetes patients with a home health care monitoring system to help patients better manage their disease. The system recorded and analyzed daily health data for each patient. If any health problems were identified, such as high blood glucose levels, then the system alerted the patients and their doctors. Researchers have found that home monitoring leads to consistent improvements in clinical outcomes for patients with pulmonary conditions and cardiac diseases.[80] Such patients show a decrease in the number of emergency visits, hospitals admissions and average hospital length of stay. So far, however, researchers have not been able to conclusively quantify the magnitude and degree of the economic benefits of home telemonitoring of patients with chronic conditions.[81]

Box 5-2: National Strategies for Health IT Around the World

Health care providers around the world use IT to reduce health care costs by increasing efficiency. A survey as early as 2002 found that more than 90 percent of physicians in Finland, Sweden, Germany, the Netherlands, the United Kingdom, and the United States used a computer in their practice.[82] The same survey also found that approximately 79 percent of U.S. doctors and 61 percent of doctors in the European Union had Internet access in their practice.[83] Individual European countries such as Finland, Sweden, and the Netherlands had more than 90 percent of doctors connected to the Internet.

Many countries are implementing national e-health strategies. Canada, for example, has established Canada Health Infoway, a federally funded, independent organization with a mission to accelerate the adoption of health IT.[84] Sweden has developed a broad agenda for health IT that includes both establishing better conditions to promote health IT (e.g., a common information and technical infrastructure) and improving health IT applications (e.g., by facilitating more information sharing and making services more available to citizens).[85] Austria has made significant progress on its national e-health strategy by implementing an E-Card system, a smart card system for patient identification and payment. In addition, Austria is in the process of deploying "Elektronische Gesundheitsakte," a national decentralized EHR network.[86] Belgium has launched pilot projects such as Coplintho to study and develop IT that could improve the quality of medical care in the home.[87]

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6. Personal Safety

Individuals have always turned to the latest technology to ensure their personal safety. In the 1850s, Edwin Holmes invented and installed the first electromechanical alarm system: when a door or window was opened, it released a spring, closing an electrical circuit and sounding the alarm, originally a gong or bell. In 1905, the American Telephone & Telegraph Company bought the Holmes Burglar Alarm business, for the first time linking alarms to emergency call systems that summoned police officers and firefighters to respond to emergencies.

Today burglar alarms in some developed nations are affordable and commonplace. In 2006, for example, 25 percent of homes in the United States had burglar alarms and 20 percent featured monitored alarms.[1] Takeup of burglar alarms has been slower in Europe, where less than 3 percent of residences have an electronic security system.[2] But information technology (IT) has permitted the introduction of new types of sensors and more opportunities for monitoring, helping make homes more secure than ever.

Moreover, as described below, IT's impact on burglar alarm systems only scratches the surface of how IT contributes to individuals' personal safety. IT contributes to individuals' personal safety by:

- securing homes from crime and other hazards
- reducing auto theft
- protecting individuals in their homes and elsewhere
- avoiding loss
- making vehicles safer
- preventing accidents
- responding to emergencies

Securing Homes from Crime and Other Hazards

Property crime in developed countries is declining, and the use of burglar alarms and other crime-stopping technology is credited, at least in part, with this trend.[3] Although entryways are most often secured by contact alarms that rely on the same basic concept invented in the 19th century of forming circuits to trigger alerts, security companies' toolkits have expanded in recent years to include a variety of new technologies.

Among the security technologies that incorporate IT are motion detectors, which are now often included as a part of standard home security packages, such as ADT's Safewatch QuickConnect System. Motion sensors trigger an alert whenever they detect motion, often used internally as a secondary layer of protection in case someone is able to circumvent door and window alarms. In addition to detecting motion, some sensors can also detect body heat, like the Brink's Dual Technology Motion Detector. Brink's also offers another advanced sensor that can detect the sound of breaking glass, helping overcome a key limitation of most window contact alarms, which go off only when a window is actually opened.

One important impact of IT in the security realm is allowing homeowners and security professionals to easily integrate multiple sensors into a single managed security system. Many modern security systems offer some form of Internet interface that gives homeowners the ability from any computer to turn systems on and off, see the current status of alarms, review through their history, and arrange for custom alerts to be sent via e-mail, short message service (SMS) text message, or automated phone call. Thus, for example, InGrid Home Security offers a system with magnetic contact alarms that install with peel-and-stick simplicity, boast an up to 10-year battery life, and form a unique two-way wireless grid to communicate with each other and notify both homeowner and monitoring center when an entry is breached or a sensor is not working. Many security systems come with remote controls that allow homeowners to arm and disarm alarm systems in the same way as locking and unlocking a car, eliminating the need to dash inside the home and enter a code to activate the alarm.

The challenge with monitored burglar alarms is that between 94 percent to 98 percent of all alarm calls to police are false—and every time police respond to a false alarm, both time and money are wasted.[4] The problem of false alarms is so rampant that it has forced police departments to start charging homeowners a fee for false alarms to offset costs. Though most consumer camera security systems allow for remote access to video and event-driven notification and recording, a limitation of such systems is that the cameras are rarely monitored 24/7; hence,

IT has permitted the introduction of new types of sensors and more opportunities for monitoring, helping make homes more secure than ever.

houses are left houses unguarded during times when homeowners are unavailable to respond to alerts.

The ability to use video security systems has long been limited by the lack of sufficient connectivity. Whereas basic alarms need only a phone line, video realistically requires broadband—the more, the better in fact, to allow a higher quality of video to be delivered. With the growing availability of high-speed broadband Internet access, monitored video is finally becoming a feasible option. Event-driven remote video monitoring services such as GOSN's SafetyBlanket protect homes by establishing a motion-sensitive zone around the house that when breached turns on lights and triggers an alert sent to the monitoring center. The system operates much like a traditional security service; however, by using remote monitoring, the control center can see what is happening and verify whether or not the alert warrants the response of the authorities, saving everyone the time, expense, and hassle of false alarms.

In the past, security systems relied solely on telephone lines to facilitate monitoring, but today cellular and broadband connections are providing alternatives that help provide reliable, always-on monitoring. High-speed Internet connections also offer the opportunity for home security systems to use video. Although business-class video systems can still be expensive, the falling cost of digital cameras, electronics, and storage makes installing remote video monitoring an affordable possibility. Equipping a house with video can be as basic as a single webcam connected to a computer equipped with low-cost software or as complex as a system with multiple cameras that feed into an onsite dedicated digital video recorder. Video is almost always available to watch live and on-demand over the Internet from any computer or even on a cell phone; and homeowners can use a service to archive video feeds offsite to obtain greater security and scalability for video data storage.

The use of a security camera, in addition to serving as a visible deterrent to intruders, offers homeowners the chance of catching a glimpse of someone breaking into a house, which may be valuable evidence when it comes to identifying and persecuting criminals. Today's digital cameras require minimal effort to install. WiLife, for example, makes a line of digital cameras that automatically create an in-home network over the home's power lines and allow remote monitoring without installing additional wiring. These cameras also can contain a variety of features such as motion detection capabilities and wireless connectivity, and night-vision. Thus, for example, users can equip a WiLife camera with an illuminator kit that emits a light that is invisible to the human eye but can be seen by the camera, allowing the camera to see in the dark at a cost much lower than buying a traditional dedicated night-vision camera. Video security systems can also include innovative features like no-show alerts. These systems allow users to set alerts for times when motion is expected, such as kids arriving home from school. If the system does not detect any motion during that predetermined time period, then it will notify the homeowner.

In addition to detecting intruders, alarm systems can detect other hazards in the home, including fire, leaks, mold, gas, and carbon monoxide. Whereas carbon monoxide alarms help keep people safe in the house, the other alarms and the use of video cameras enable homeowners to keep tabs on their property while away—a capability that can be especially vital to owners of vacation properties because what may start as a small incident, like a burst water pipe, can grow into something significant (e.g., transitioning from water damage to the dreaded mold) if left unaddressed over the many months that these buildings often remain vacant.

Reducing Auto Theft

Often the biggest ticket property crime for individuals involves auto theft. Every year, millions of motor vehicles are stolen worldwide, resulting in billions of dollars in losses.[5] In 2006, in the United States alone, there were 1.2 million motor vehicle thefts. IT-powered solutions, however, are helping to reduce this problem.[6]

Perhaps the most effective car security devices are those that make cars intelligent and start only for their owner, thereby stopping thieves from stealing the vehicle in the first place. Currently, for example, owners can equip their vehicle with aftermarket devices to use biometrics, such as their fingerprint, as the key to unlock their car or start the ignition. More common are offerings like the Power Lock, which allows a vehicle to start only when the driver has a wireless transponder on their keychain or touches an electronic access key to a reader installed in the dashboard.

Another innovative example comes from Auto-txt, which combines the ability to disable vehicles with another ability—namely, remote monitoring, the second major category of auto theft prevention technologies. To use Auto-txt, an owner installs a device on the vehicle to authenticate the driver through a software application running on any Bluetooth device a driver may have, like a cell phone. If someone tries driving the vehicle without disarming it, an alert will be sent to a response center that will call the vehicle's owner to confirm the vehicle's status and, when necessary, disable the vehicle remotely.

Although the technologies just described can help stop auto theft, systems like those offered by LoJack can help recover stolen vehicles. To use LoJack, a technician installs a small, hidden radio transceiver on the vehicle. If an owner reports a LoJack-protected vehicle as stolen, then when police enter the crime report into the state police crime computer, they will discover the LoJack number. Using this number, the police can remotely activate the unit on the car, thereby leading the authorities to its exact location. In some states, car insurances companies offer discounts of up to 35 percent to cars equipped with such systems.[7]

Protecting Individuals in Their Homes and Elsewhere

The tale of how IT is making people more secure has many more chapters beyond stopping bad guys from stealing things. In fact, many of the same or analogous technologies employed for that purpose can be utilized to monitor other situations where keeping an eye on things remotely can help keep people and places safe.

Home medical alert systems can help protect individuals in the home. Services like ADT's Companion Service provide a base station that doubles as a phone, as well as a wristband, pendant, or stationary personal help button that when pushed sends an alert to a special monitoring center staffed by people who have been trained to deal with senior citizens sensitively. Such services enable individuals in poor health to gain a new level of protection in case they can not get to a phone during a medical emergency. Technologies such as QuietCare's home medical alert system provide additional benefits. Using wireless activity sensors placed throughout a home, this medical alert system can track a home occupant's movements, upload that information over a phone line to a remote computer, identify normal movement patterns, and then send an alert if it detects a significant change in the occupant's behavior. This system helps identify both abrupt and acute changes and long-term and subtle conditions. Targeted primarily for adults with age-related limitations, QuietCare is allowing individuals to live at home on their own longer while also providing peace of mind that they are safe.

IT can also provide a means for protecting individuals receiving care from others, including older adults living in long-term care centers, patients in mental hospitals, and young children in daycare. Even though many institutional facilities offer safe environments, the unfortunate reality is that abuse and neglect is found in some settings. One tool to reduce such incidents is technologies such as Web-enabled cameras, which help individuals keep tabs on loved ones. Families can use password-protected websites not just to check in on their family member's well-being but also to monitor the care the family members is receiving. Remote monitoring is even filling a niche for tech-savvy pet lovers. Some cameras are now being marketed as perfect for watching pets while away from home, helping their owners make sure they are eating and moving around.

Parents also use IT to more easily monitor the safety of their children, including children with disabilities. Child locator devices allow parents to put a small tag on their child (or their child's clothing) to electronically monitor the child's location without having to be physically tethered to them. Such devices can alert parents if their child has left their proximity and help locate a child who is unresponsive to verbal requests. Such devices can also be valuable to guardians and caretakers of individuals with Alzheimer's disease.

IT can also be used by parents and guardians to help monitor the safety of their wards outside the home. GPS-enabled cell phones, for example, come in a variety of formats, including kid-friendly designs. Using built-in GPS capabilities, parents can access an online interface to locate their kids at any time. Other devices, such as the Wherify GPS Child Locator Watch build on this concept. This child-size watch uses GPS so parents can know where their kids are at all times. Additionally, the parents can set alerts to watch certain areas so that if their kid does not show up at a specified location, such as the field for soccer practice, an alert will be sent. Whether it is someone old, someone young, or something furry, IT is empowering people to monitor the status of those that are important to them and in so doing help ensure their safety.

Avoiding Loss

IT can help reduce the chance of losing things—from mundane items (like a TV remote control) to essential items (like a set of keys) to vitally important items (like a handheld glucose meter) and increase the odds of finding lost items quickly.

Losing something is an information failure. To help make things that have been lost easier to find, a variety of solutions offer the ability to attach radio-frequency-emitting tags that communicate with a handheld device. Using these tags, a lost item can be found quickly either by activating an audio alarm on the thing that is lost or by following visual cues on the handheld device that can point the user in the right direction.

RFID tags can help prevent loss. RFID tags are similar to radio-frequency-emitting tags but do not necessarily continuously emit signals: Passive RFID tags are simple integrated circuits that lie dormant until in the presence of an antenna that reads information; and active RFID tags contain an internal power source that allows them to send out signals to a receiver. A prime example of how the use of RFID can prevent loss can be found in the 2009 Ford F-150, which will feature a system designed to help owners never leave a worksite without all their tools. To accomplish this, truck owners will attach RFID tags to their tools, which are read by the RFID antennas built into the truck, and a real-time inventory can be accessed through a touchscreen display in the dashboard. If the truck senses that all of the tools are not on board, then it will notify the driver.

RFID can be used for everything from keyless locks and safes to garage doors that will only open for authorized cars without the need to push a button.

The future of RFID extends far beyond preventing loss. This technology can be used for everything from keyless locks and safes to garage doors that will only open for authorized cars without the need to push a button. RFID can be used to create computers that turn on only in the presence of the appropriate RFID tag or pet doors that respond to a specific pet collar. The possibilities for using RFID are limitless.

The final point to touch on in the realm of preventing and recovering from loss is the loss of one's self. Getting lost is not only frustrating; it can also be potentially be dangerous, leading people into bad neighborhoods or down unsafe roads. The good news is that IT is helping to solve this problem. From simply having a cell phone on hand to call for directions to having a dedicated GPS unit in the car that can give directions for finding the intended destination, using IT no one ever has to be lost again.

Making Vehicles Safer

IT has its greatest impact on safety when technology gets smart and gains the ability to size up situations and pursue actions on its own in order to save people from harm and prevent accidents without human intervention. Smart technologies can make dangerous situations safer by automatically sensing dangers and taking action to prevent harm. Many of these innovations can be seen in automobiles because vehicles are using IT to become more aware of their surroundings. Vehicles with collision mitigation can use radar or Wi-Fi and GPS to detect the proximity of other cars and then employ anticipatory braking, either a slight jolt as a warning or the beginnings of a full stop. Volvo's City Safety system even uses a computerized steering-control system so that the car can turn to avoid an accident when braking. Other innovations include vehicles that trigger an alert when they sense another vehicle is in the blind spot when changing lanes and vehicles that sound an alarm when they start to drift out of their lane. Some cars utilize radar to measure the distance between its rear and whatever is behind it. Others now feature cameras that actually show what is behind the vehicle on a screen in the dashboard. So in addition to improving the safety of highway driving, IT can help prevent the often minor, though sometimes serious, accidents from backing up improperly.

Engineers are also making the roads safer by using IT to design vehicles that prevent accidents from reckless driving. A feature known as electronic stability control, for example, manipulates a vehicle's brakes and throttle, and soon steering, in order to keep the vehicle from spinning out on sharp curves or during sudden maneuvers. A feature known as rollover protection uses gyroscopic sensors to gauge when a quick turn threatens to roll over a top-heavy sports utility vehicle, deploying the countermeasures of enhanced traction, stability controls, and pulsing brakes to prevent this from happening.

Even when technologies cannot prevent an accident, some technologies can help keep an eye out for passengers during and after an incident. Smart airbags, for example, know if someone is sitting in the passenger seat and can sense the size of that occupant in order to deploy airbags in the most effective way possible. Some airbags can even gauge the severity of an accident as it is happening and inflate more for worse accidents and less for those that are less severe.

The best thing about the advances of IT in cars is that the majority of the new technologies do what they do without the driver's input. Cars are becoming smart enough to transform awareness into action in an effort to keep passengers safe.

Preventing Accidents

IT is being integrated into every facet of life through smart technologies in an effort to improve personal safety and prevent accidents. Take the SawStop for example. Touted as the "world's safest table saw," it includes an electronic detection system that runs an electrical signal onto the blade. When the blade then hits flesh, the saw registers a drop in that signal and triggers a fast-acting brake that prevents the user from getting cut. Taking something dangerous like a saw and making it smart is now helping save fingers and other appendages from unintended cuts and amputations. There are also ground fault circuit interrupters like the ShockBuster that prevent accidental electrocution. Plug this product into the wall outlet, then plug in whatever electrical appliance is needed. Now, whenever a ground fault is detected, be it from a frayed wire or contact between electronics and water, it will automatically shut off power to the device. Some homes are now being built with these types of outlets right from the start, removing the need to buy additional hardware. Furthermore, the future points to a day where these capabilities are manufactured into every device, thereby dramatically lessening the danger of having things like hair dryers near bathtubs.

IT is also helping reduce accidents caused from damaging underground hazardous liquid and gas pipelines. The United States has more than 2 million miles of onshore oil and natural gas pipelines, operated by roughly 3,000 companies.[8] Unmapped pipelines can cause significant financial and health risks to construction crews or others who might unknowingly dig into them. Companies like ViaLogy are using remote sensors and geographic informa-

As local governments and utility companies amass more GIS data on underground pipes and cabling, workers will be able to use GPS-enabled equipment to avoid potential hazards.

tion system (GIS) analytics to create digital pipeline maps.[9] In addition, the U.S. Department of Transportation produces a searchable online public map of gas transmission pipelines and hazardous liquid trunklines.[10] Because digital images are produced and updated to the maps in real time, these maps are far more accurate and efficient than their paper ancestors. In the near future, as local governments and utility companies amass more GIS data on underground pipes and cabling, workers will be able to use GPS-enabled equipment to avoid potential hazards. Already companies like SmartFleet use GPS technology to help workers in remote oilfields avoid terrain that is unsafe for construction equipment.[11]

IT can even make devices that are known to be dangerous if put into the wrong hands, such as guns, safer through technologies that lock out unauthorized users and help prevent accidents. These include products like the Speed Release Gun Lock, which allows a gun owner to lock down the trigger with a secret code stored in the device. Also available are biometric gun safes that use fingerprints as keys. And in the future, fingerprint and palmprint recognition will be built into the gun itself, helping ensure that it only works for the person or people authorized to use it.

As electronics get smaller, more powerful, and less expensive, IT is going to be more pervasive and embedded in more devices. Many of the new devices will be equipped with sensors to detect dangerous situations and take proactive steps to help keep people safe. Thus, for example, smart pill bottles will remind patients to take their pills with dynamically updated electronic displays. They will register when a patient misses a dosage or is taking too much and wirelessly notify their doctor. They will know when they are running low and automatically order refills with the pharmacy. All with the intent of making sure patients, especially those with chronic conditions that need regular medication, avoid the needless complications associated with irregular dosages. Trials with different versions of the smart pill bottle concept are under way, and concepts that will make use of technologies like e-paper as they mature are being designed.

Food labels will know when items have passed their expiration dates, and smart refrigerators will alert individuals when food has been sitting on the shelf a suspiciously long time. Technologies such as smart milk cartons will know when their contents have soured, and smart cans will sense the presence of unwanted contents like botulism.[12] Already more advanced food labeling is used in Japan, where DoCoMo Sentsu and the Marine Fishery Systems Association worked together to create a 2D barcode system for labeling fish. Using this system, consumers can scan the fish with their cell phones in order to learn where and when a fish was caught and even details such as what fishery or which boat caught the fish.[13]

When shifting circumstances can result in accidents, sensors and alarms can be used to monitor and alert users to dangerous conditions so that they may avoid them. As people continue to rely more heavily on IT, solutions like those described above will introduce new opportunities for IT to be used to help prevent accidents and keep people safe.

Responding to Emergencies

Despite all of the innovations that help keep people safe, there will always be emergencies. Even the smartest cars cannot avoid every accident, and the most secure, well-monitored homes cannot stop everything bad that might happen. Here too the rise of IT is helping individuals get help to resolve emergency situations with as little loss as possible.

Individuals can use in-vehicle IT to get assistance faster during an emergency. Following an accident, networked services such as BMW Assist and GM OnStar enable calls for help to be made from inside the car. They feature GPS capabilities that can guide emergency response teams, which is critical given the ease with which one can get lost while driving. Next-generation versions of this technology promise to deliver additional information automatically, like informing first responders about the nature of the crash, the point of impact, which seats were occupied, and which airbags deployed. This information can then be passed on to emergency rooms so that they can begin preparations to accept injured passengers, ultimately helping improve the medical care received following an accident.[14]

In fact, much of this information is currently available but the problem is getting the relevant pieces of information automatically to first responders. Currently, 911 responders have to make multiple calls to track down logistical information such as emergency airlift and hospital surgical team availability. Automatically linking the relevant parties in an emergency can significantly cut down on response time and save lives. Furthermore, new systems are being developed that combined multiple sources of information to create an "injury algorithm" that predicts the probability of risk. For example, computers can combine data from a crash showing how fast a car decelerated and whether or not the airbag was deployed with electronic medical data on the victim to forecast the expected severity of injury. This information can then be passed on to emergency rooms so that they can begin preparations to accept injured passengers, ultimately helping improve the medical care received following an accident.[15]

IT is also helping private organizations communicate with their community during an emergency. For example, some universities have implemented IT systems that can notify their entire student and teacher populations via text messages sent to cell phones to stay inside during an emergency situation, such as a school shooting. Though not yet universally deployed, these systems hold great potential for helping keep emergencies contained and not allow them to devolve into chaos.

Even when the use of IT cannot prevent emergencies, it can play a significant role in helping manage an emergency once it is already happened. (For more information, see Chapter 13: Public Safety.)

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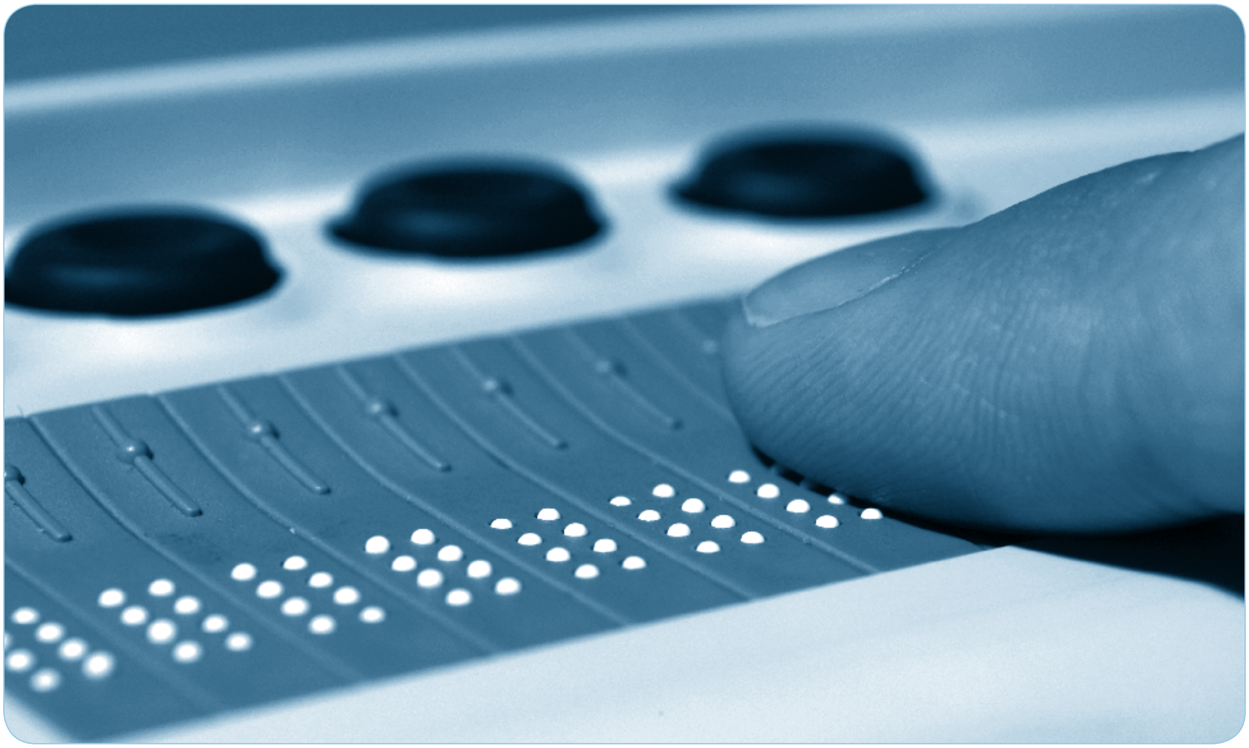

Almost 10 percent of the world's population—650 million people—live with some type of disability.[1] A disability is any physical, sensory, or cognitive impairment that makes daily activities more difficult. Many people are born with a disability. Others acquire a disability later in life, from an accident, an illness, or the aging process. Many older individuals are diagnosed with chronic conditions that lead to functional or cognitive disabilities. In the United States, for example, about 15 percent of people over the age of 65 require some form of assistance with their basic daily activities.[2]

For much of history, many people with disabilities have had to rely on technologies that were designed for the nondisabled community. Even technology specifically designed for people with disabilities—such as Braille text for people with a visual impairment or text telephones (TTY) for people with a hearing disability—could require a high learning curve, be limited in availability, or have a high cost because of its specialized nature.

Information is no longer constrained to a single medium. Instead, IT has created a world where users can choose the format in which they want to consume information.

Recently, however, the shift from analog technology to digital technology has eliminated many of these barriers. The reason is simple: digital information can easily be converted into voice, text, or even physical patterns (e.g., Braille), allowing the development of many more low-cost, readily available general purpose devices that also can be used by people with disabilities.

The digital era has led to many advances in technology that have directly improved the quality of life for the disabled community. As discussed below, technology that improves accessibility for people with disabilities generally falls into three categories:

- assistive technology (technology designed specifically to improve a disabled person's functional capabilities)
- adaptive technology (technology that provides a mechanism that allows people with disabilities to use technology that would otherwise be inaccessible to them)
- accessible technology (technology that has many broad applications but helps remove barriers and make the world more accessible for people with disabilities)

Assistive Technology

Assistive technology for individuals with disabilities is technology designed to improve the functional capabilities of such individuals. It includes a wide range of devices and services, including IT-enabled prosthetics and implants, custom computer interfaces, and accessible communication tools.

In the medical arena, researchers have designed IT-enabled devices for people with disabilities that radically increase their functional capabilities, including improved hearing for individuals with hearing disabilities and improved vision for people with visual disabilities. (For more information, see *Chapter 5: Health Care*.) In addition, IT provides people with disabilities with many new tools to use to assist them in their daily lives.

IT helps individuals lead independent lives while minimizing the risks associated with solitude. Currently, for example, older adults and individuals with disabilities can use a personal emergency response system so that with the push of a button they can call for medical assistance. Personal emergency response devices typically consist of two components: a wearable wireless transmitter and a telephone unit that connects to an emergency response center. Such devices can particularly help adults who are at risk of a stroke or falling live independently. They can also save money by reducing the length of time for inpatient hospital care or nursing home care.[3]

Monitoring individuals with personal emergency response devices could cost as little as $50 per month—a drop in the bucket compared with the costs of inpatient care. Although such technology is not currently widespread, a recent study by AARP found that most older adults were willing to use high-tech safety devices at home. Furthermore, the technological possibilities are growing fast as emergency alert systems for elderly and disabled individuals such as these prove their worth. "Memory bracelets" that vibrate when it's time for the wearer to take medicine or go to a doctor's appointment, for example, have been developed by Intel. Intel has also created sensor-infused carpets, or "magic carpets," that measure gait and notify medical officials in the event of a fall.[4]

Technology also offers much hope for helping children with developmental disabilities. Autistic children, for example, often lack verbal communication skills and instead rely on nonverbal communication techniques such as pointing or leading. Unfortunately, researchers report that the nonverbal communication techniques they use may be considered "inappropriate (e.g., guiding a stranger's hand)"[5] or, even when considered socially acceptable, may "result in frequent communicative breakdowns." To avoid this problem, autistic children can learn to communicate their needs by using a voice-output communication aid (VOCA). A VOCA is a handheld electronic device that produces prerecorded audio messages at the press of a button. Thus, it improves communication and reduces the frustration children feel when they cannot communicate.[6]

Technology can also provide opportunities for social interaction and education—something that adults and children with disabilities too often miss out on. In the United States and Canada, for example, the PEBBLES Project has developed a technology solution to address the educational and social needs of the more than half a million children who require long-term hospital care. Using two child-sized robots—one in the hospital and one in the classroom—linked by a high-speed Internet connection, a hospitalized child can participate in classroom learning and interactions. The robots can transmit audio, video, and text and even have a robotic hand to get attention, giving these children a complete telepresence in their regular classroom. They are also mobile, allowing student-to-student interactions to take place outside the classroom in places such as the hallway or lunchroom.[7]

Adaptive Technology

Adaptive technology is technology that provides a mechanism that allows people with disabilities to use technology that would otherwise be inaccessible to them. Because it makes information accessible in more ways and formats, IT is playing an important role in improving access to information among individuals with visual and hearing disabilities.

Text-to-speech technology, for example, helps users with vision impairments to be able to "read" materials that are written. Computer screen readers, such as JAWS, and screen magnifiers help make computer output accessible for visually impaired users. In Pensacola, Florida, Publishers Circulation Fulfillment's call center uses an application that interfaces with call centers and lets agents with visual disabilities hear computer-driven data.[8] Tactile displays can convert electronic text on a computer or other similar device to Braille. Similarly, the U.S. National Institute of Standards and Technology (NIST) has created a tactile graphic display for readers with visual disabilities. The tactile display raises and lowers a series of small pins that adjust to create patterns based on an image; since the pins adjust automatically, individuals can use the display to feel multiple images in quick succession.[9]

Some technology developers have adapted handheld personal computers (PCs) for use by visually impaired users. Using add-on peripherals such as a Braille display or voice synthesizer for output, users can customize their personal digital assistants (PDAs) for their needs. Thus, for example, a user with a visual disability can equip his or her PDA with an optional bar code reader to electronically identify objects in a store. Once radio-frequency identification (RFID) tags become widely used for individual consumer items, identifying consumer goods will be even easier for such shoppers. Engineers have even developed an improved version of the classic magnifying glass: a portable video device that can magnify objects, make light print darker, and increase the contrast between lettering and the background.[10]

Digital technology is also empowering people with visual disabilities by providing them with much more information when they are outside their home. A technology combining a global positioning system (GPS) with an accessible PDA, for example, enables users with visual disabilities to navigate and orient themselves, even in unfamiliar settings. With this technology, the PDA issues voice prompts, telling the person where he or she is and how to get to their destination (e.g., "turn right"). In addition, users of this technology can connect to databases containing information about points of interest, such as restaurants or transit stations, to find their way to previously unvisited locations. Some regions, including Fairfax County, Virginia, have even compiled databases of obstacles such telephone poles, fire hydrants, and sidewalk cracks to aid with mobility.[11] Although a GPS is certainly not intended to take the place of mobility training, it does serve as a helpful electronic guide and tool.

Accessible Technology

Accessible technology is technology that has many broad applications but helps remove barriers and make the world more accessible for people with disabilities, giving them more access to information, communication, and independence. The fact that digital information can easily be converted into voice, text, or even physical patterns has led to the development of many low-cost, readily available general purpose devices that also can be used by people with disabilities.

Many accessible technologies were not originally designed to address specific disabilities but were rather adapted for them. Speech recognition software, for example, has many uses such as dictation or automated telephone systems; however, the technology can also provide independence for quadriplegics by allowing them to control a computer with their voice. Similarly, a German research institute designed a hands-free computer interface for computers in an industrial setting that uses eye movement to control a cursor; the researchers quickly realized the technology's usefulness for quadriplegics.[12]

IT allows almost any action—including vibrations of the vocal cords and tongue movements—to be converted into an electronic signal that can control another electronic device. Thus, for example, individuals unable to speak because of a neurological disorder can use a neckband called Audeo that picks up nerve signals in the neck (generated when a person tries to speak), relays them wirelessly to a computer, and then plays back those words using a synthesized computerized voice. This device can also be used to facilitate physical movement by, for example, allowing an individual to control a wheelchair with her voice. Quadriplegics now have many options for interfacing with a computer or IT-enabled devices such as artificial limbs. Researchers have even designed systems that allow individuals to control a cursor using their brain waves.[13]

The widespread digitization of information enables multiple modes of communication, each with its own unique features and benefits. Thus, it reduces barriers to communication for people with disabilities and provides new opportunities for social interaction. Many technologies offer high levels of flexibility and customization for users with different needs. Thus, for example, people with hearing disabilities, who have little use for voice telephone features on a cell phone, can instead opt to use the texting, instant messaging, and e-mail features on these devices. In fact, some cellular phone companies offer mobile phone plans exclusively for individuals with hearing disabilities.[14] Users with hearing disabilities can similarly bypass traditional media that rely on voice communication and instead use videoconferencing services to communicate through sign language or lip reading. Using speech recognition software, broadcasters can offer closed captioning for all of their programs, even live programs, at a lower cost than that of using a human stenographer.

Similarly, the widespread digitization of information has created a paradigm shift that benefits people with disabilities. Information is no longer constrained to a single medium. Instead, information technology has created a world where users can choose the format in which they want to consume information. Twenty years ago, for example, only a paper copy of the *New York Times* was available. Now individuals can choose to read the newspaper in print, online, or on a cell phone or other mobile device. Visually impaired subscribers can use text-to-voice applications to hear the newspaper and subscribe to podcasts from leading *New York Times* columnists.

Many people with disabilities have found that high-speed broadband Internet access provides them with many unprecedented opportunities to access information and services. Whether a person has a mobility impairment or chronic fatigue, options such as telecare and telework can improve their quality of life. Telework allows people with disabilities to work from their home, a convenience that can mean the difference between employment and unemployment for individuals unable to commute. In addition, working from home may provide a person with a disability a more accessible and flexible work environment. Telework also benefits companies who can use this benefit to retain productive employees who face short-term or long-term disabilities.

Finally, accessible technology can help ensure that voters with disabilities have the same rights and independence as other voters. One of the fundamental components of modern democracies is the use of anonymous ballot in elections. Anonymous ballots help prevent voter coercion and vote selling. Until the recent introduction of electronic voting machines, many citizens with disabilities could not vote privately or independently. Voters with certain visual disabilities, as well as many voters with mobility limitations such as arthritis or quadriplegics, for example, cannot use voting systems such as punch card systems, lever machines, or paper and pencil methods unless they have assistance. Electronic voting machines can incorporate accessible design features to allow greater accessibility for individuals with disabilities. Voters with visual disabilities can hear ballot choices through voice-to-text technology in electronic voting machines; and mobility-impaired voters can operate the electronic voting machines with accessible buttons or even "sip-and-puff" straw-like devices for quadriplegics.[15]

Moving Forward with Accessibility

For people with disabilities, the development of modern IT offers unprecedented levels of access to information and communication and improves their functional capabilities. Unfortunately, many people with disabilities do not have access to computers or other IT because the technology is beyond their means. The technological divide between disabled and nondisabled individuals is often striking. A 2006 study, for example, reported that 58 percent of individuals without disabilities used a computer at home, as compared with 30 percent of individuals with a disability.[16] Home computer use is especially important for the members of the disabled community because many of them do not have access to the Internet at work. Overall, the disabled community is generally poorer and has a higher rate of unemployment than the general population. Adaptive technology also imposes additional costs on disabled users who wish to use otherwise technology that is otherwise inaccessible to them.

Fortunately, as the price of computing continues to decline, much IT is becoming more affordable.[17] In addition, many government and nongovernmental organizations support programs to increase access to people with disabilities. In Korea, for example, the government sponsors over 8,000 community centers where the public can get free Internet access, and it also runs a program to provide people with disabilities free computers and training.[18]

Developers of new technology must continue to design products with accessibility for people with disabilities in mind. Too often accessibility is forgotten in the design process. One study in 2006 found, for example, that only three out of 100 of the top website destinations on the Internet passed the minimum international standards for accessibility.[19] Fortunately, content developers increasingly rely on structured data formats to manage growing amounts of data and data are increasingly flowing to accessible formats. In addition, improvements in search and data-mining algorithms means that software may some day be able to extract accessible information from otherwise inaccessible data sources.

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8. Recreation and Entertainment

Technology—from radio and record players to television and digital video disc (DVD) players—has a long history of opening up new ways to entertain ourselves. But the information technology (IT) revolution is enabling endless possibilities to improve, expand, and enhance our recreational and entertainment experiences. Indeed, as discussed below, IT is redefining consumers' relationships with traditional media and pointing the way to a more entertaining future by improving the quality of entertainment, offering more choices in entertainment, allowing more control of the media experience, and enabling consumers to participate in creating media.

Improving the Quality of Entertainment

Technology has long been bringing about improvements in the quality of entertainment, whether via the development of clearer sounding FM radio, more vivid color TVs, or better sounding LP records. But digital technology has taken the quality of entertainment to a whole new level because it can produce images and sounds that analog technology could never match.

Digital technology works by breaking up pictures or sounds into discrete bits (1s and 0s) and reassembling them for playback. Dramatic advances in processing power, storage, displays, and transmission mean that the number of bits keeps growing, thus improving quality. It is easy to remember watching movies on videocassette recorders (VCRs) and seeing the distortion on the screen as the videotape lost its integrity or listening to the hiss of vinyl records that had been played one time too many.

Digital technology provides the same high-quality sound or image time after time with no degradation in quality—one reason that DVD technology, which introduced high-quality digital video to the mass market, gained such rapid and widespread adoption. DVDs look so much better than video home system (VHS) tapes, and the quality of DVDs does not degrade over time with multiple playbacks. Similarly, music compact discs (CDs) sound perfect every time they are played.

Now high-definition (HD) video and audio has made possible sounds and pictures that are sharper and clearer than ever. As prices of high-definition TVs (HDTVs) have decreased, sales of HDTVs have been growing.[1] And the format of the new Blu-ray (made with a blue laser) disc—which is the same size as a DVD but allows far greater storage—enables consumers to watch movies in HD on video discs.

But the future of high-quality video delivery is not limited to physical media such as DVDs. Cable, satellite, and telephone companies in the increasingly competitive video marketplace have made the availability of HD video a key battleground in their bid for new subscribers. For that reason, they have all invested heavily in upgrading their networks' digital capacity in order to handle more HD channels and greater amounts of on-demand HD content. Today many networks deliver dozens of HD channels and hundreds of hours of on-demand HD content. Tomorrow that growth should only continue as more HD content gets produced, TV providers expand their capacity for offering HD, and more consumers buy new HDTV sets.[2]

The expansion of faster broadband networks is also making it easier to download HD video from the Internet—one reason why HD video is beginning to appear more regularly on the Internet. In the United States, all four major TV networks now offer free full-length episodes of first-run TV shows online and on-demand, delivering full-screen video that, if not HD quality, is at least DVD quality—a big rung up the evolutionary ladder from the coaster-sized window of a typical YouTube video.

True HD video is also beginning to be available for download on the Internet through legal online movie purveyors like CinemaNow or BitTorrent. Streaming HD with instant-on-demand playback is also beginning to appear, as evidenced by TheHDWeb.com—a high-profile initiative powered by leading content delivery network Akamai that demonstrated HD video streaming is possible. The proof-of-concept initiative was sponsored by Verizon FiOS (Fiber Optic Service). Consumers need a relatively high-speed Internet connection, a minimum of a steady 7.5 Mbps connection, to watch a single HD video stream.

Digital technology has taken the quality of entertainment to a whole new level because it can produce images and sounds that analog technology could never match.

As amazing as HD video is, though, it is only the beginning. Quad HD, a video standard with four times the resolution of HD, is already being developed for use in movie theaters as a way to attract moviegoers back to the theater by delivering an experience that can not yet be replicated in a home theater. In addition, Japan has recently ratified the Ultra HD standard, which has 16 times the resolution of HD, as their national goal for what they want to be broadcasting in by 2012.

And out on the horizon is the tantalizing possibility of three-dimensional TV without those funny glasses—think hologram, like Princess Leia in Star Wars when R2D2 shows her saying, "Help me Obi-Won Kenobi"—a technology that is currently working in the labs but is still a few years off from being commercially available for consumers. The future of interactive video displays also comes straight out of the movies. Technologies like IO2Technology's Heliodisplay project images into mid-air, viewable from multiple angles, using standard inputs like DVD video, and requiring no special hardware or software to view the images. The more advanced interactive video systems can even register hand movements and translate them into actions. Such technology is truly science fiction brought to life, fundamentally expanding our relationship with information. Soon, fully realized three-dimensional TV will be possible in the home.

The quality of the touchscreens found in many digital devices is also improving. Microsoft Surface, for example, is a 30-inch tablelike display that not only registers touch and gestures in order to navigate menus but also senses what devices are placed on it. On an even bigger scale, touchscreens the size of walls have been demonstrated at tradeshows promising a future where ads are interactive, allowing people to touch them to learn more. TV channels like CNN have replaced green screens with touchscreens as a way for hosts to interact with and display information during shows.

The trend to higher quality is evident in digital cameras, too. The quality of pictures from the original digital cameras was good but usually not as good as the pictures from high-quality cameras that relied on chemical film processing. Over time, however, the resolution (pixel quality) afforded by digital cameras has grown significantly. The cameras built into cell phones today feature the same 1- to 3-megapixel resolution found in consumer cameras a few years ago. In addition, many sub-$200 digital cameras today can take pictures with 6- to 8-megapixel resolution, roughly equating to film. Digital movie cameras are improving in quality, as well. The first digital movie cameras were competing with the decidedly inferior technology of VHS rather than film. Now consumer-priced digital movie cameras have HD capabilities, offering a quality of picture that rivals film and leaves VHS far behind in the dust.

Although the impact of digital technology on the quality of video may be more readily apparent, digital audio is also improving in quality. A string of new audio formats like Super Audio CD and DVD-Audio have entered the market with the goal of dethroning audio CDs by offering additional features like high-

Box 8-1: The Networked Living Room

The networked living room is an important technological revolution for entertainment that is just now cresting over the horizon. As recently as a couple years ago, living rooms were hardly ever networked. People watched TV on their TV, listened to music on the stereo, and accessed the Internet on their computer.

Today all of these devices are coming together. Thus, for example, digital video recorders (DVRs) can download video from the Internet and show it on a TV. Likewise, gaming consoles like the Xbox 360 let consumers purchase or rent TV shows and movies and download them right into their living room. Indeed, high-speed broadband, the widespread availability of content, and a networked living room have led some to eschew traditional TV service altogether to rely solely on Internet video.

What could take all this even further is the upcoming potential of TVs that can connect directly to the Internet without the need for a separate box. The first versions of these networked TVs are already on the market, though they tend to only allow access to "walled gardens" of content. In addition, networked Blu-ray players will enable users to play trailers for upcoming movies, download additional foreign language tracks not included in the original release, and even participate in interactive gaming. Internet-enabled consumer electronics, such as music players that can play Internet radio stations, will allow Internet applications to break free from the desktop and become more integrated into our lives. As more Internet-enabled technologies such as music players become available, people will be able to rely on networked experiences for entertainment even if they do not have a computer.

er quality content. Currently, however, CDs remain the most popular medium for audio. The main competition to CDs has come from the Internet—for example, via the digital downloads available through online stores like iTunes. Although iTunes uses the Advanced Audio Coding (AAC) format, most audio files distributed online use the MP3 format, which compresses files to make them smaller. The quality of audio downloads in MP3 format is no better than a CD and often worse, though still good enough to satisfy most consumers.

Audio formats like MP3, AAC, and Ogg Vorbis can encode files at higher bitrates and thus produce better quality audio than a CD, but they do take up more storage space. The reason higher quality audio has not become mainstream is that the mass market has deemed CD-quality good enough. For that reason too, the latest digital broadcast technologies like satellite and HD radio tend to aspire only to CD quality. Still HD radio is a significant improvement over existing terrestrial radio, offering a far higher dynamic range and frequency response that leads to better sounding high and low notes.

The area of entertainment that has shown the biggest improvement in quality is probably high-tech gaming. Today's high-definition, fast-moving, and lifelike video games bear little resemblance to games like Pong that were such hits in the 1970s and 1980s. Indeed, the digital revolution has enabled the video game industry in the United States to grow into a nearly $10 billion-a-year business.[3] In some countries, including South Korea, online gaming has become such a phenomenon that there are entire TV channels devoted to covering the top players and tournaments. One reason for the popularity of gaming is that higher quality sound and video enable gaming experiences that come much closer to simulating real life. In the past couple of years, with the release of the Microsoft Xbox 360 and Sony PlayStation 3 video game consoles, gaming has taken a huge step forward in this direction. Both of these consoles are massively powerful machines, so powerful that some researchers have been known to string together Sony PlayStation 3s to crunch numbers in lieu of renting time on supercomputers.[4]

The development of video games always lags behind the computing power and capacity of new hardware platforms, but the games that are on the market today have reached the point where the quality of every element of their graphics look as good if not better than the prerendered cut scenes of games 10 years ago. Whereas there used to be a stark difference between gameplay and cut scenes, today the two look seamless, with some high-end games achieving photorealistic HD images. New hardware has also led to the introduction of new types of remote controllers for video game consoles. The remote controller for the Nintendo Wii, for example, has received much attention for its innovation combination of an accelerometer and a light sensor so that the device can register motions such as pointing and swinging.

The same trends leading to higher quality graphics in video console games also apply to games played on personal computers. The combination of faster processors, more memory dedicated specifically to graphics rendering, and bigger hard drives has brought forth a new age of high-quality gaming where realistic simulations of everything from driving a racecar to piloting a plane to commanding a World War II platoon is possible. Moreover, the ability for games to be more lifelike and have greater functionality is enabling the creation of a host of games that contribute to education and training.

Offering More Entertainment Choices

For many years, consumers have had only a handful of entertainment choices. Before cable TV, most consumers had a choice of just a few TV channels, assuming they were even close enough to a TV broadcaster to get reception. Before the Internet, consumers could get only the books and music that their local store sold. The digital revolution has led to an explosion of entertainment choices—and it is not too unrealistic to postulate that at sometime in the future, people will have access online to virtually every song, video, book, and photo ever published.

This expansion of choices in entertainment can be seen in the growing number of channels available on subscription video and audio services. On the TV side of things, choice has definitely increased with the introduction of digital TV technologies like digital cable, satellite TV, and Internet Protocol TV (IPTV). The move from analog to digital broadcasts now under way will allow hundreds of additional channels to be delivered over existing networks. In addition, because of competition in the TV marketplace, TV providers continue to invest in increasing the size of the on-demand libraries they can offer their customers.[5] As a result, children, for example, can choose from vast selections of kid-friendly and educational content.

It is not too unrealistic to postulate that at sometime in the future, people will have access online to virtually every song, video, book, and photo ever published.

In radio, satellite radio is providing consumers at home, in their cars, and elsewhere vastly more music choices than the limited number of stations available in any one local over-the-air radio market. The fierce competition between XM and Sirius—the merger of which was tentatively approved by the Federal Communications Commission in July 2008[6] —drove both companies to commit big dollars towards locking up exclusive deals with a host of high-profile media properties. As a result, anyone can tune in to any Major League Baseball or National Football League game on satellite radio rather than turning on the radio to listen to the home team and can also listen to a diverse array of original shows being produced by established stars like Oprah Winfrey and Bob Dylan.

The place where the expansion in entertainment choices is really playing out is the Internet. Indeed, the variety of video, audio, books, photos, and other entertainment now available online is breathtaking. Beyond opening up entertainment content in people's home countries, the Internet is making domestic entertainment content available internationally. Thus, for example, people can listen to Internet radio stations from around the world to hear news and information from abroad or to enjoy cultural or entertainment programming from distant countries. In addition, with bandwidth increasing to support IPTV to the home, some companies are offering a wide range of foreign language video broadcasting.

TV networks and many cable networks now offer full-length first-run episodes on the Internet to watch on-demand for free. Some networks even make entire seasons of shows available, and most TV networks, large and small, have at least some number of short video clips on their website. Movies can be also purchased online for viewing. Although there are still some limitations in terms of what movies are available on what terms (e.g., rental versus retail), there is no limit to the number of titles and types of business models that can be implemented online.

To see the online entertainment choices available now to consumers, it is worth looking at what is happening in sports broadcasting. In the past, sports fans wanting to watch a game of their favorite team had to hope it was broadcast on their local TV—an unlikely event if their favorite team was not the team in their local media market. Now the Internet is giving people vastly increased choices in the sports events they can watch. In the United States, all the major sports networks, at a minimum, deliver clips of game highlights online; and most sports networks offer free and paid packages for people who want to watch entire events live and on-demand, with coverage that far outstrips that which is available on TV. During the National Collegiate Athletic Association basketball playoffs, for example, CBS streams live video of all the games online, while the local TV affiliate shows only one game at a time. The expansion of options in sports broadcasting is not limited to domestic sports either. The Internet is opening up the world's arenas to anyone interested in sports that do not get enough mainstream coverage in their home countries. Take soccer or cricket, two sports with huge international followings. Fans of soccer or cricket who do not get coverage in their home country can pay a monthly fee and start watching the games and matches over the Internet so they do not have to miss out.

The IT revolution is not just providing more entertainment choices from the standard fare of TV networks and studios; it is also opening up a wide array of entertainment choices that previously could only be viewed or heard live by the people who were there. Indeed, the biggest Internet video success story to date has been the video-sharing site YouTube, which hosts user-submitted content. YouTube and

Box 8-2: Entertainment in Your Pocket

The amount and variety of entertainment that can fit into a pocket seems to know no bounds as continuing technological innovation has increased the capacity and opportunity of handheld devices. The 800-pound gorilla of mobile media for the 21st century has been Apple's iPod, with more than 170 million units sold. The iPod redefined the ease with which massive libraries of music could be enjoyed through its signature click-wheel interface.[7] It also introduced a new model for music distribution through the close integration between the iPod device and iTunes service.

Over time, Apple has continued to develop the iPod platform into revolutionary new form factors. One innovation has been the push into smaller and smaller profiles, eventually resulting in an MP3 player called the iPod shuffle that is only 1.5 inch by 1.5 inch and weighs a mere half ounce. Another other major iPod innovation has been the big viewing window and touchscreen of the iPhone and iPod Touch. Both of these introduced a new high for the ratio of screen-to-device size, offering an unmatched viewing experience for a mobile device. Their multitouch interfaces rely on gestures rather than pushing button to makes tasks like mobile Web browsing more robust and intuitive than ever.

The market for portable media players continues to gain new entrants as company after company tries to dethrone the iPod. Though no company has captured the public's attention the way Apple has, a number of companies have developed products that have established profitable niches by focusing on offering greater capacity, bigger screens, and additional features like built-in radio tuners.

Consumers are also gaining more choice in leveraging the multimedia capabilities of their mobile phones. Although Apple's iPhone introduced in 2007 revolutionized the mobile Web browsing experience, every major wireless carrier is making aggressive moves into offering music, video, and gaming services to their customers through their phones. Today people can watch individual video clips, tune into live TV, listen to music paid for by individual song or as a subscription service, and download and install a whole host of games, all on their mobile phones. Purchasing and listening to music on a mobile phone has proven so popular in Japan that it accounts for 91 percent of all digital music sales in that country.[8]

There are still many barriers to using mobile media. Mobile phones themselves, for example, are limited in terms of storage capacity, screen size, and, often, network connectivity. In addition, it is uncertain where mobile entertainment services fit into consumers' overall entertainment choices. Mobile phones cannot yet replace things like TV so consumers can not substitute one medium for another. But with a number of companies investing heavily in building out services along with the never-ending evolution in the capabilities of these mobile devices, there is little doubt that mobile media will be a key part of the future of entertainment.

websites like it allow anyone to upload a video and share it with the world. By drawing upon the "power of the crowd," these sites host deep and diverse libraries that feature everything from funny home movies to news and TV clips to video diaries to professionally produced original shows.

Such sharing is what allows for the viral growth some videos achieve. A few people see a particular video and like it; they share it either privately with some friends or publicly on a different website; and then more people continue to see and share the video with others in their social network. For those who think the video choices on the Internet are a "vast wasteland," it is important to note that within all the content are some real gems. One of the most popular Google videos, for example, is the "Amazing Juggling Finale," featuring performer Chris Bliss. *The Washington Post* described the video as follows:

> *It is just a guy, three balls, and an ornate stage at some unnamed live event. The Beatles' melancholy "Golden Slumbers" begins playing on a loudspeaker, and the gray-haired man in the dark shirt and pants is suddenly juggling in perfect sync to the music. For 4 1/2 minutes, he tosses and grabs, his hands and body language capturing the pace and mood of the Fab Four as they build to the rousing three-song finale of the "Abbey Road" album. When the music ends and the last ball is caught, the crowd is on its*

feet, roaring. The man takes a bow and walks off the stage.[9]

What the digital revolution did was allow this juggling performance to be seen and enjoyed by millions who otherwise would never have had a chance to see it. The video clip was actually from a 2002 comedy festival and remained a largely unnoticed posting on Bliss's personal website until early 2006, when someone came across it and sent to a group of friends. The video quickly became an Internet sensation and, thanks to the wonders of viral marketing, was viewed more than 20 million times by mid-April 2006.

Not only have the video choices on the Internet exploded; the audio choices on the Internet have also exploded. It used to be that radio listeners were limited to the stations their antenna could pick up. Now through Internet radio, listeners can tune in to online versions of over-the-air radio stations from around the world that also stream over the Web, as well as from thousands of online-only radio stations created by anyone with enough passion for music. Likewise, it used to be that music CDs listeners bought were limited by what CDs were available in the local store unless they wanted to wait for a package to arrive in the mail. Now through digital downloads, listeners can access online stores that provide instant access to millions of tracks. Increasingly, listeners can get music directly from their favorite artist, even if they have yet to make a recording deal with a major studio. More and more music is being created exclusively for distribution over the Internet.[10]

Finally, consumers have vastly more choices for gaming than ever before. All three major game consoles—Microsoft Xbox, Sony PlayStation, and Nintendo Wii—now offer some form of a virtual console on the Internet, where users can download games rather than having to get the game on disc. The the Xbox 360's Live Marketplace, for example, lets users find and buy games from independent developers. In addition, there are thousands of casual games available online that come in all shapes and sizes. And beyond these is the growing marketplace of games offered by mobile providers to be played on cell phones.

Allowing More Control of the Media Experience

Beyond providing a much wider array of higher quality entertainment, IT is empowering consumers to exert more control over their media experience. The idea of giving consumers control over their media experience began in large part with the VCR, which allowed for "timeshifting" of TV programming—that is, recording TV shows at one time and watching them at another time when it is convenient.

Timesharing has been taken to a new level with the introduction of the digital video recorder (DVR), which has made recording shows, storing them, and later playing them back as easy as pushing a button. More than one out of every five households in the United States already uses a DVR to timeshift TV programming, and the number is growing rapidly.[11]

One of the greatest things about IT is that it offers portability, allowing media users to experience their media—whether it be it video, audio, or photos—in a variety of place. IT enables not just timeshifting of TV and other programming but also "placeshifting" of such programming. A device from Sling Media known as a Slingbox, for example, sits between a person's cable box and TV set and enables the person's at-home TV service to be made available through any broadband-enabled computer. The placeshifting concept includes all instances where someone takes a digital file to watch or listen to it somewhere other than where it was downloaded—for example, watching a TV show on a portable media player such as an iPod.

The ability to control one's media also includes the rise of the networked household. Networked DVRs allow multiple TVs to be equipped with small boxes that give any TV in the house access to the content stored on a central DVR—another example of placeshifting allowed by IT. A wide variety of IT-enabled products—including the functionality of the Media Extender for Xbox 360, AppleTV, and a new product from Sling Media called SlingCatcher—also make it possible to send media from a computer to a TV. Sitting in middle of all these trends is the in-home media server, like HP's MediaSmart Server, which serves as the repository for all of a user's media and makes those media accessible to the user both at home and remotely.

Box 8-3: Entertainment in the Car

Like everything in the 21st century, cars are increasingly going digital, loading up with entertainment opportunities, and getting online, all thanks to IT. As recently as a decade ago, installing video entertainment technology in cars was largely unheard of outside of high-end conversion vans with built-in TVs. But as liquid crystal display (LCD) screens have grown smaller and less expensive, and consumers have grown more demanding, the paradigm of in-car video entertainment has shifted dramatically.

Today many family vehicles like minivans come equipped with LCD screens and digital video disc (DVD) players as standard features. Some are even being sold with gaming consoles already built in, or at least with entertainment centers ready to accept their input. Beyond that, it is now possible to install mobile satellite television receivers in cars. In addition, auto manufacturers are working with consumer electronics companies like Apple to equip their vehicles with iPod docking stations on the dashboard.

But these are all turn-of-the-century technologies. In the years ahead, there seems to be no end to the ways in IT and entertainment will become mobile. Two big revolutions on the way are in-car storage and connectivity. Already, some higher end car models are being offered with built-in media servers, which are basically hard drives that allow for storage of audio and video without needing to carry discs. Developers are also working to enhance in-car connectivity using wireless broadband technologies like 3G (the third generation of developments in wireless technology). In addition to offering Web surfing from the backseat of cars and traffic updates to in-car navigation systems, in-car connectivity also offers a more elegant solution for loading audio and video onto an in-car media server.

Enabling Consumers to Participate in Creating Media

In the old economy, producing video and audio entertainment was something that only professionals and large companies did. A large part of the reason was that recording and editing video and audio required costly, powerful, dedicated software and hardware that was hard to use. Moreover, distributing a video or audio required millions of dollars and access to distribution networks linked to movie theaters and retail stores.

In today's digital economy, IT has reduced many of the barriers to production and distribution of video and audio entertainment by consumers. Digital technology has made it cheaper and quicker to produce media than ever before. Inexpensive cameras and audio recorders abound, and powerful software allows regular people to do editing on regular computers. In fact, IT makes it possible for limited editing to be done right inside an Internet browser.

Combining IT-enabled media production technologies with an open platform for sharing media like YouTube has resulted in a remarkable revolution in the attitudes of consumers: Instead of just leaning back to watch videos and other media, they are now also leaning forward to participate in production. With today's technology, people can make a video diary with a webcam, produce an amateur short film, or upload their photos and home movies to share with friends and family. As a result, millions of homemade videos, songs, and text are now available online. A measure of the success of the phenomenon is that 80.4 million viewers in the United States watched 3.42 billion videos on YouTube in February 2008 alone.[12] Users of YouTube's website watch hundreds of millions of videos and upload hundreds of thousands of videos every day; and 10 hours of new content is uploaded to the website every minute.[13]

And users are not just producing videos. Many electronic games allow users to create and share new challenges or levels to complete in the game. Also on the rise are gaming platforms like Fyrebug.com that provide basic gaming engines, images, and sound effects to let users create their own customized games.

All of these examples leverage the power of the crowd in the creation of video and audio entertainment. Rather than relying solely on professionals to produce content, companies now rely on the vast segment of the public that enjoys participating in the creative process. By leveraging their own talents, consumers are gaining access to a much wider variety of content while at the same time feeling empowered to engage in the process of creating media of their own.

There can be no understating the impact IT has had, is having, and will continue to have on entertainment. IT has given us access to more entertainment content in more places in more packages than ever before—and the diversity and quality of entertainment options continues to grow. Some of the technologies covered in this chapter will undoubtedly fade away, new ones will most certainly rise to take their place, and others still will find their way into the hearts and minds of the public. What can be said with utmost certainty, though, is that the use of IT to enable entertainment will continue to grow and evolve and reshape our understanding of how we relate to the experience of consuming audio, video, games well on into the future.

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9. Access to Information

One of the most important impacts of information technology (IT) is making individuals' access to information more convenient and efficient. The Internet is where the IT revolution is most evident as it now contains all kinds of information touching every part of modern life. New technologies are making all that information easier to find and verify while also expanding the opportunities to interact with, contribute to, and view all sorts of information. The IT revolution is not limited to the Internet, though, because other technologies such as kiosks and portable storage are making information accessible from anywhere. These advances are creating a world where libraries have no walls and keep no hours, where information can be found easily assuming it does not find the seeker first, and where the way people physically interact with information is expanding in exciting new ways.

Growth of Information Online

Throughout the 20th century, most information was passively received through TV, radio, newspapers, and magazines. Finding information meant searching through whatever books sat on a bookshelf or in the local library. These traditional publishing paradigms restricted the creation of new information sources and access to this information. But the paradigm has shifted dramatically over the last 20 years as books have given way to websites and new sources of information have flooded the Internet.

With a few strokes on a computer keyboard, Internet users can learn about a foreign destination they wish to travel to, find reviews about local restaurants, or discover the best neighborhood bicycle routes. Indeed, it is hard to imagine living without the Internet, yet not too long ago if one wanted to learn about Mozart, driving to the local library was often the only option. Now with search engines like Google and online encyclopedias like Wikipedia, volumes on virtually any subject are but a click away.

In education, students are no longer limited by the walls of a library or the expertise of a single teacher because they can access resources from a global classroom and connect with both fellow learners and subject matter experts regardless of geographic proximity. In health care, patients can study their conditions using the same materials as their doctors, share insights with people suffering from similar maladies, and get not just a second opinion but the best opinion on how to proceed with various treatments. In government, citizens no longer have to wait in lines, fill out forms, and dig through paper records to find the information they need to be productive members of society because they can get the materials they need online.

The impact of IT on improving individuals' lives through improving their access to information has been profound, making daily activities more efficient and robust. In personal finance, for example, balancing a checkbook is arguably a thing of the past as anyone can instantly check their balance using a computer, ATM machine, or cell phone. Most every bank in developed countries now has a website that allows customers to learn about and apply for loans, make transfers, and set up automated payments. Studies have shown that the more services someone uses from an online banking provider, the more pleased they become at its ease of use in comparison to traditional banking.[1]

For individuals looking to manage their money, investment strategies used to be limited by the lack of access to robust, real-time information. Now many individuals choose to forgo stockbrokers to manage their own investments because there is very little information available to professionals that cannot be found by amateurs through online research. In addition, the process of buying a stock or bond is just a few clicks away. In Japan, online trading has exploded, with the number of accounts at Japanese electronic brokerage firms growing from fewer than 300,000 to nearly 8 million since 1999, and Internet trading now accounts for more than a quarter of all equity trades in the country.[2]

Similarly, in personal consumption, shopping has been transformed through the availability of online information. Just about anything that can be bought in a store can be bought online, even perishables like groceries—and consumers have embraced these possibilities around the world, with more than 85 percent of the world's online population having purchased something using the Internet.[3] Also instead of relying on the Sunday paper to learn when sales

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are on, one can quickly and easily compare prices between multiple stores online. Currently, for example, two-thirds of U.S. consumers use the Internet to research purchases before going to the store.[4] Most significant of all, consumers are no longer limited to the opinions of friends and the endorsements of celebrities to influence their decisions when making purchases because reviews written by real people are available for almost any product or service to help consumers make more informed decisions about how to most effectively spend their money. Companies can even use IT to put information online about each specific product the company ships. Thus, for example, computer manufacturers like Dell allow customers to look up product information based on the unique serial numbers printed on each device. Another company, EggFusion, puts a code on every egg it sells that allows consumers to log onto the company's website and find information about the freshness of each individual egg.[5]

Improved access to information also allows individuals to learn about things without having to be physically present. Virtual tours of houses, for example, save prospective homebuyers hours on the road going from property to property by letting them first see inside a building before deciding if it is worth a trip to view the property in person. In addition, homeowners now have access to the same information as real estate agents, which is helping enable some sellers to forgo using an agent altogether, thereby allowing them to save the money it costs to pay a commission; homebuyers can now obtain a lot of information about a property on their own without having to rely solely on the insights of a real estate agent.

Many aspects of life continue to be improved by the ever-increasing availability and quantity of information accessible online. This trend will only continue as more information comes online and new tools are developed to making it easier to find and access the information.

The Power of People to Expand Information Availability and Access

One of the most striking aspects of the IT revolution is how it enables new sources of information to be created by lowering the barriers of publishing to allow anyone to contribute to the Internet's collective knowledge base.

Blogs have become platforms for individuals to have their voices heard. Though most blogs do not deal with matters of substance, many are being written by subject matter experts, be they professional or amateur, sharing their insight into trends, commenting on news, and providing free analysis and new perspectives that previously might never have found the light of day. Blogs provide an opportunity to find the unfiltered opinions of people around the world, from consumers to innovators, and they are now often being used by industry as well to announce new products, services, and hires in a less structured and often more informative way than a press release.

Tapping the collective wisdom of the crowd to compile more comprehensive sources of information is the defining characteristic of a wiki, websites that allow users to contribute by adding or modifying content. The most prominent example is Wikipedia.org, an online encyclopedia created and updated by its users. But wikis are also increasingly being used inside corporations, schools, and government agencies in order to create a public or private knowledge base to help the organization run more efficiently. Other online content management systems, such as Microsoft SharePoint similarly facilitate information sharing and provide a dynamic resource for online collaboration.

In addition to creating new information resources, the power of people is being tapped to help make information easier to find. At a most basic level are initiatives like that at the U.S. Library of Congress, which now offers the ability to e-mail or chat with a librarian over the Internet. So now, instead of having to hunt and peck through the shelves to find the right book, scholars can just send a request to a librarian and the librarian will help find it for them.

Taking this a step further, a number of sites have sprung up that allow anyone to pose questions to subject matter experts and receive specific answers. One such site is AllExperts.com, which features a host of volunteer experts ready to answer questions on topics ranging from how to create great animation to computational biology to tips for dealing with chronic pain. Simply select an expert, pose a question, and receive an answer. Combining the ability to ask questions of experts with the power of the collective consciousness are sites like Yahoo! Answers, where questions can be posed to an open, global audience of potential experts. Anyone can answer and anyone reading the question can weigh in on which answer is their favorite, helping determine which answers to trust as they rise to the top.

User input helps direct people to new information and engage in better decisionmaking. User reviews help online shoppers decide which product to buy and which merchant to trust. Home chefs can search through online recipes and choose dishes with the best ratings and find the most useful tips. Internet radio broadcasters like Pandora even help listeners discover new content by using algorithms to recommend specific music based on user feedback. Similarly, a key feature of Netflix's online movie rental system is its user rating system, which allows the company to recommend movies for users on the basis of their feedback and rental history.

Where human power really revolutionizes the capabilities of search to deliver high quality, highly relevant information is through a site like Mahalo.com. Users enter keywords into Mahalo like a regular search engine, but the difference is that for the most popular search terms, Mahalo enlists freelancers and full-time guides to create the best search results pages they can. Unlike most search engines, which count the number of times a keyword appears and how many sites link to a page, Mahalo uses human reviewers to organize sources into verified lists of results for the most popular keywords, enabling people to find the best possible resources for their topic of interest.

Finding Information Expeditiously

The improvements being made in the ability to find information are not limited to people power, though, as a number of exciting advances are being made in expanding old-fashioned search while also revolutionizing the ability to find information without having to look for it.

Finding Needles in the Haystack

When someone wants to find something but does not know where to look, the place to start for most is a search engine. Input a keyword or three and instantly the user is presented with a series of links to sites from across the Web. Search engines come in many shapes and sizes in order to cater to the needs of different audiences. Highlighting the global adoption of search and the Internet as a source of information for a global audience is the fact that four of the top ten most popular search engines in the world are based outside of the United States: Alibaba and Baidu (China), NHN (South Korea), Yandex (Russia).[6]

The same keyword search paradigm—and often even the same technology—is now in use on most every website as well, giving users the ability to search an entire site by entering a keyword in order to quickly find the specific information they need rather than having to hunt through all the individual pages. In addition, apart from indexing text, search engines increasingly index images, audio, and video. The challenge with searching multimedia content using keywords is that the search engine must rely on metadata or tags to determine the content. Even when multimedia lacks identifying tags, though, developers have found innovative ways to search multimedia content. The website blinkx.com, for example, uses a combination of speech recognition and video analysis software to identify the contents of an audio or video file and create metadata "on the fly" without human involvement. Going a step further, companies such as EveryZing have developed products that leverage speech recognition technology to index the complete contents of audio and video files, allowing users not just to search these files but also to jump right to the particular point in a media file that contains the pertinent information.

One difficulty with all these search engines is that they require users to specify the right words to find the right answers. Introduced to overcome this and add an element of serendipity are relational searches. Although relational searches encompass a wide range of things, at their core, relational searches suggest topics related to an initial search, often displaying these relationships in graphical form. An example is VisualThesaurus.com. Type in a word and results are shown as a spider web around the primary term. Click on an orbiting word and it becomes the center with a whole new set of analogous words around it. Using this technique, users do not have to know the specific word to find what they are looking for.

The future of search can be found at the nexus of relational and natural language search in a concept called the Semantic Web. What this boils down to is computers beginning to understand the meaning of things, associating the word "dog" with canine, companion, and animal, and recognizing when the meaning of words change because of context. Some of the first applications claiming to introduce the Semantic Web are just coming online now—like Powerset, a semantic search engine that searches Wikipedia.org entries on the basis of the meaning of a topic, phrase, or question the user enters not just by matching up the specific words the user enters. Eventually, computers will better understand what users are searching for and therefore be able to more efficiently route them to the content that is most relevant to their needs. In the meantime, there are thousands of search engines from hundreds of countries.[7]

The IT revolution has enabled new sources of information to be created by lowering the barriers of publishing to allow anyone to contribute to the Internet's collective knowledge base.

Search is even proving helpful in non-Internet, bricks-and-mortar scenarios. For example, some book and electronics stores have installed kiosks that allow shoppers to more easily find what they are looking for in what are often massive stores while also providing a way to check on the availability of a product at other outlets of the same chain if that particular store happens to be out of stock.

Finding Local Information

The information that is most relevant to people is that which deals with where they live, for such information has the most direct impact on individuals' day-to-day lives. Until recently, for example, most people relied on newsletters and the yellow pages for information such as the time of the next neighborhood association meeting or the location of a store that sells a particular product. Finding geographically relevant information, though still difficult, is getting easier. In the developed world, most local media outlets—whether print, radio, or television—have an online presence stocked with stories related to specific geographic markets. They also typically have tools that help citizens stay in touch with the comings and goings of their community. In addition, specialty aggregators such as Yahoo's Upcoming.org pull together event listings from multiple sites so people can always know when or if something fun is happening in their community.

Global positioning system (GPS)-enabled phones allow users to find georelevant information based on their precise location at any given moment. Applications like Lightpole allow for robust local search where users can enter keywords like restaurants and instantly know what is close by, not just restaurants but also more specific information like happy hours and Wi-Fi hotspots. Sites like Google Maps build on this to allow for awareness of things like traffic conditions on the roads between user and destination, even going so far as to offer StreetView in some cities, which provides an on-the-ground perspective of what a particular destination looks like.

Even for individuals not near a computer, Google offers 1-800-GOOG-411 in the United States and Canada. Users that dial that number reach an automated 411 information service. State the city and either name or type of business and the system's speech recognition retrieves the appropriate results and even offers to connect the caller. Not only is GOOG-411 quicker and easier than traditional 411 where there is often a wait to talk to a human operator, it is also free.

Information That Finds the User

The common thread between all the modes of content discovery just discussed is that they require the user to actively try to find information. But IT also enables a host of ways for information to find users without them having to look for it first. Travelers can have airlines automatically contact them when their flight is delayed. Banks can notify customers when they are about to overdraw an account. Customers can sign up to be alerted about new sales at their favorite stores before they are widely advertised. In these ways, IT helps enhance quality of life by getting information to people before they even know to look for it.

Another tool that helps users automatically receive content is RSS, short for Really Simple Syndication. Using RSS, users can subscribe to a website and receive updates when new information is posted on that website. Subscribing to an RSS feed is like subscribing to get a magazine delivered to the home rather than having to go to the store to buy it. RSS readers also allow users to create custom searches that will alert the user when it finds new content that matches their interests. In this way, users can have relevant information find them rather than them having to go out and find it. Businesses use this same model to create a digital memo system that automatically notifies relevant parties when information such as company policy changes.

RSS is not limited to webpages because it can also be used to enable multimedia feeds. The most common of multimedia feeds are podcasts, which are typically recorded Internet radio shows. Users can download podcasts on thousands of topics—from learning to speak a foreign language to university lectures to congressional hearings. Users can even set up a program like iTunes not only to download podcasts automatically but also to synchronize them with a portable media player, meaning the content is ready for them to listen to within moments of becoming available. Although podcasting got off to a slow start, from June 2007 to March 2008 the percentage of global Internet users who download podcasts more than doubled, from just over 20 percent to 45 percent.[8]

Accessing Information from Anywhere

Another important impact of IT is allowing users to access the information they need whenever they need it. For example, a person on the road needing access to a file sitting on a desktop computer back home can use software to remotely access the desktop computer. Professionals on the go like salespeople can also tap into computers and databases back at the office through virtual private networks, giving them the ability to retrieve critical documents whenever they are needed. A popular consumer extension of this concept are services that allow for remote access to multimedia content, like Orb Networks, which provides users instant access to the photos, music, videos, and other digital content on their personal computer at home from any Internet-connected computer or device.

There is a growing realization that in order to thrive in the digital age, access to the Internet and an understanding of how to use it are essential.

Despite the many benefits of accessing information over the Internet, there is still something to be said for physical digital media that do not require connectivity to work and which continue to grow larger in capacity while getting smaller in size. USB flash drives, for example, make for a convenient and speedy way to transfer information, and their large capacity means a lot of data can fit into a pocket. USB flash drives are only one example of the rise of ubiquitous portable storage. There are pens now that can record and store voice messages and some can even register what is being written. Personal media players such as iPods contain storage that can just as well be used for documents and data as for music and movies. For example, Nike+ is a system that combines sensors in shoes with a receiver that plugs into an iPod nano to keep track of data like the amount of time and distance ran and calories burned. As a result, runners on the go have not only their music in their pocket but also a host of other information.

Another instance of IT enabling access to information whenever it is needed is in circumstances where language is a barrier. Nothing can be more frustrating to a traveler or businessperson than having the right person to talk to but not the right words. But now a host of technologies are making on-the-go translation possible. Handheld electronic dictionaries, for example, can not only show words and definitions but can also speak them; and they can even use speech recognition to translate spoken words or phrases from one language to another. In addition, services like Kwingo.net deliver industry-specific phrases and terms to cell phones for areas like construction and food service.

In the early days of the Internet, lots of information was online, but many people lacked Internet access, so they could not take advantage of the information. Today access to digital information is growing as more households become connected to the Internet. Currently, the majority of households in many parts of the developed world have access to broadband Internet service.[9] In addition, wireless networks of all shapes and sizes are expanding the reach of broadband in both developed and developing countries. Satellite and WiMAX networks promise to rapidly increase the number of people who can access the Internet, and Wi-Fi networks have become so ubiquitous that in many urban and suburban areas around the world free Wi-Fi access can be found in restaurants, coffee shops, and hotels.[10] In addition, Internet cafes allow anyone to rent time on an Internet-enabled computer. In China alone there are reported to be more than 100,000 Internet cafes.[11] The availability of Internet access in such cafes is especially important for rural areas in China, where there are an average of only 2.7 computers for every 100 people. More than half of rural Chinese users access the Internet in these cafes.[12]

In addition, cell phones have achieved mainstream success, though the high-speed cellular networks that serve them have been more of a mixed bag. Although nearly 500 million cell phone users worldwide subscribe to a next generation 3G network, Asian- Pacific countries that have aggressively deployed the technology account for nearly half of that number.[13] The advantages of 3G are higher data speeds that allow for more robust mobile applications, especially those involving video. These high-speed wireless networks are especially useful for individuals with a job where they are on the go all of the time and may not have a regular office at which to gain access to information. Whereas it used to be professions like taxi driver or long-distance trucker meant only being able to know what is going on through the radio and citizens' band radio, today those same people can access everything available on a computer wherever on the road they might be.

Internet access is also being provided for free at public institutions like libraries. Through the efforts of programs like the Bill & Melinda Gates Foundation's U.S. Libraries Initiative, nearly every public library in the United States now offers free access to computers and the Internet.[14] Although similar initiatives are being pursued around the world, they often run into challenges associated with insufficient connectivity. In Africa, for example, many universities have as much connectivity as an average U.S. household but they share that connection among all of the students, many of whom have given up trying to use the universities' computers because of their slow speed and have been forced to pay high rates for Internet access at Internet cafes.[15] There is a growing realization that in order to thrive in the digital age, access to the Internet and an understanding of how to use it are essential.

Dedicated kiosks also provide access to digital information. These often single-purpose terminals are enabling access to information including travel information, banking information, event schedules, weather, and job applications. Such kiosks provide a dedicated alternative to having to go out and find information on the Internet, putting digital information right at a user's fingertips.

There is no end to the impact of IT on expanding, enhancing, and revolutionizing our access to and relationship with information. IT is not only making a limitless amount of new information available; it is also making it easier to find the information that is most relevant to our needs while also redefining how we physically relate to that information.

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10. Environment

With populations exploding and economies expanding, humanity faces a number of pressing environmental challenges in the 21st century. Our thirst for oil and other fossil fuels has rapidly depleted supplies of these finite resources, and the pollution that results from consuming them is choking the air of the world's most populous cities and slowly warming the planet. Meanwhile, the Earth's rich biodiversity is dwindling at an alarming rate as rainforests are threatened and growing numbers of species become endangered by human development. Indeed, the global environmental picture is a troubled one.

The good news is that with growing awareness of the myriad environmental problems come efforts to find innovative ways to assess and combat environmental degradation, many of which rely on information technology (IT). It would be hyperbole to say that IT is the solution to the world's environmental problems, but IT is dramatically enhancing scientists' understanding of the environment and helping to ameliorate our impact on the planet's delicate ecosystems.

As it is in many aspects of life, IT is reshaping our understanding of the natural environment and humanity's impact on it, while at the same time helping to mitigate the associated problems. From advanced, efficient recycling programs to sensor networks to gauge the impact of human-produced carbon dioxide to DNA analysis to save endangered species, IT has become a critical piece of many attempts to address today's pressing environmental issues.

Creating a Cleaner World: Pollution and Waste Mitigation

By enabling sophisticated technologies to address air and water pollution, understand global warming and aquatic ecosystems, and facilitate recycling, IT is creating a cleaner, more sustainable world. IT is critical to many of the technologies being employed to counter humanity's growing ecological footprint.

Addressing Air Pollution

Air pollution levels have generally declined in advanced industrialized nations, but they remain a problem, particularly for some pollutants. Moreover, air pollution levels are worsening in many developing nations that are beginning to industrialize.

Scientists increasingly rely on IT-enabled tools to understand and tackle pollution. IT is central to the development of new tools enabling advanced monitoring of air pollution, including tracking and managing its sources and understanding better its impacts and how to mitigate them. Thus, for example, sophisticated computer models allow researchers to predict local atmospheric pollution levels in order to impose effective controls.

To study and alleviate smog in large cities, scientists can now deploy sensor networks to determine when and where pollution is worst, as well to ascertain the immediate causes of the pollution. Understanding the particular mix of causes of pollution in turn allows decisionmakers to evaluate cost-effective and feasible solutions. One example of IT-driven pollution monitoring involves the work of a team of Massachusetts Institute of Technology (MIT) scientists in Mexico City. With some of the worst pollution in the world, Mexico City exceeds the limit for acceptable air pollution close to 300 days a year. To address the problem, the MIT scientists used IT instruments to measure real-time pollution levels throughout the city, including a van equipped with global positioning system (GPS) and advanced pollution-detection equipment to measure neighborhood pollution levels, as well as to follow various vehicles, tracking their emissions.[1] From their extensive measurements, the MIT scientists have constructed advanced computer models to reflect more accurately Mexico City's pollution and give policymakers better tools to address the problem.

Harvard University and BBN Technologies have similarly installed over 100 wireless sensors on streetlights to collect data on pollution and weather factors at the city-block level throughout the city of Cambridge, Massachusetts.[2] This project—called CitySense—will offer scientists more precise measurements of weather phenomena, including how pollution from various sources disperses throughout the city. The CitySense system circumvents the battery life issues that such wireless networks typical face because the sensors draw electricity from the city's streetlights. In addition to supporting long-term environmental experiments to learn about mi-

IT is dramatically enhancing scientists' understanding of the environment and helping to ameliorate our impact on the planet's delicate ecosystems.

croclimates within the city, the CitySense project will serve as an "open laboratory," allowing researchers from around the world to access the project's data online and run research experiments using the network of nodes.[3]

Elsewhere, researchers using satellite data from the National Oceanic and Atmospheric Administration (NOAA) are tracking ozone, a critical ingredient in smog. Ozone, which can form when fossil fuel pollution reacts with sunlight, absorbs specific wavelengths of light and can therefore be detected by satellite imaging. Ozone shows up as a precursor to smog, so the new tracking tool allows researchers to anticipate ozone and smog, resulting in better pollution modeling and improved health advisories.[4] It is conceivable that one day a GPS-based fee per miles traveled system will replace the gas tax. Such a system would allow fees for travel to be increased on days health officials predict high local levels of pollutants, so as to give travelers incentives to drive less.

Yet another example of the application of IT to pollution tracking is the Vulcan Project. With funding from NASA and the U.S. Department of Energy, researchers from Purdue University, Colorado State, and Lawrence Berkeley National Labs have built a new, interactive mapping program—the Vulcan Project—that uses data collected by the U.S. Environmental Protection Agency and U.S. Department of Energy, among others, to pinpoint and quantify sources of carbon emissions in the United States.[5] By showing carbon dioxide emissions at a local level throughout the United States on an hourly basis, the Vulcan Project offers information on such emissions that are 100 times more detailed than was previously available.[6] In addition to tracking pollution sources by economic subsector and fuel type, the project supports advanced atmospheric modeling of pollution over time.

The Hestia Project, another project now under way, sets out to do worldwide what the Vulcan Project has done for tracking carbon emissions in the United States. The precise tracking and mapping of carbon emissions being done by the Vulcan and Hestia projects are important not just for understanding emission sources and geographic concentrations but also because they provide the critical information that underpins carbon-trading schemes.

Although the Vulcan Project is an important resource for the scientific and policy communities, there is another tool that offers the general public an easily accessible glimpse at the pollution in one's neighborhood. This tool—called MapEcos—is a relatively simple application that uses Google Maps to highlight, with color-coded points, data from the U.S. Environmental Protection Agency on toxic emissions from industrial sources. MapEcos reveals information about specific polluters (e.g., type of toxic emissions emitted by a particular business and how that entity's emissions compare with other businesses in the industry, county, state, and country) and offers links for obtaining more information.[7] Tools like MapEcos are but one example of the way in which IT is dramatically changing the information landscape for the public—organizing and making available useful information that empowers citizens to make informed decisions.

Understanding Global Warming

Global warming has emerged as a threat of the first magnitude, and IT is enabling better, more timely measurement of climate changes around the world. The Earth's atmosphere is a remarkably complex system, so modeling future temperatures requires the sort of complex calculations only made possible by high-powered computing. A better understanding of the nature of global warming enables policymakers to take measures to mitigate global warming—or failing those, to prepare for the harmful worldwide effects of global warming, such as rising sea levels and more severe weather events.

Scientists have enlisted a wide range of IT tools in their attempts to gain a better understanding both of the processes contributing to a warming Earth and of the extent to which the climate has changed. Such tools include extensive sensor networks to collect readings, as well as airplanes equipped with advanced data measurement instruments for collecting measurements in the upper atmosphere. A plane being deployed in the arctic by National Oceanic and Atmospheric Administration researchers, for example, has 30 airborne sensors that collect data that can be used to produce a detailed simulation of the chain of chemical reactions that arctic pollution causes and that increase ice melting.[8] For collecting critical data underneath enormous icebergs in Greenland, the National Research Council of Canada has begun using an autonomous unmanned submarine that avoids the danger of sending humans into an area where splintering and crashing ice could spell death at any moment.[9] This submarine collects data on how quickly the ice in Greenland is melting, information that will be valuable in computer simulations to forecast glacial melting and improve understanding of how quickly sea levels will rise.

Though the specific efforts just described are very important, the real promise for the future lies with an integrated, worldwide sensor network currently under development—namely, the Global Earth Observation System of Systems (GEOSS). The GEOSS network is an international effort involving over 70 countries that will collect data pertaining not only to a changing climate but also to air quality more generally. By integrating worldwide data from satellite observations, ground-based sensors, and other sources, including mobile ones, scientists will be able to cull data to develop computer simulations that model atmospheric conditions—including weather, pollution from forest fires, and future global warming—more accurately than ever before.[10] And indeed if an integrated, worldwide sensor network had ubiquitous sensors—perhaps by being installed on vehicles (with the owners' permission) and transmitted wirelessly—it would not be unrealistic to imagine the creation of a national or even international real-time air pollution map.

Another area where computer modeling is playing an important role is in improving our understanding of the potential adverse effects of global warming. Bangladesh, for example, has begun developing maps that identify areas of the country on a precise scale that will be most vulnerable to severe droughts, storms, and flooding in a warmer world, so that the country can begin preparing for these events.[11] In addition, Internet users around the world can now go online and see virtual maps showing how rising sea levels may affect their local communities or how global warming is impacting glaciers.[12]

Researchers are also using soil-erosion models based on a geographic information system (GIS) to predict the effects of global warming on crop yields worldwide.[13] Although traditional crop surveys use questionnaires distributed to farmers to develop estimates of crop yields, global warming has increased the volatility and dynamism of crop yields. In 2007, the U.S. Department of Agriculture overestimated its annual national corn yield prediction by 200 million bushels; other analysts, who used GIS and weather forecasts to collect hundreds of gigabytes of data and then create digital soil maps, predicted the harvest correctly.

IT does not offer a panacea for global warming, but understanding the phenomenon of global warming would be nearly impossible without the tools that IT offers researchers. And as described below, IT will play a role in solving global warming by shifting the energy system to become less carbon-intensive.

Addressing Water Pollution

Water pollution—the contamination of bodies of water such as lakes, rivers, oceans, and groundwater caused by human activities—is a serious problem. Though water covers 71 percent of the Earth's surface, drinking water is relatively scarce. The potable water found in lakes, rivers, and in the ground accounts for only 0.65 percent of the total water on earth. Moreover, aquatic ecosystems are thoroughly interconnected (all rivers eventually flow to the oceans, etc.), and pollution in one place can have wide-ranging effects far beyond the immediate source.

IT has become an indispensable tool in understanding and managing water pollution. Most developed nations strictly regulate "point sources" of water pollution, such as contaminated discharge from a factory or sewage treatment plant into a river, but identifying and regulating "nonpoint sources" of water pollution is much more challenging. Nonpoint source pollution is caused when stormwater runoff picks up pollutants such as herbicides, fertilizers, grease, pet waste, and toxic chemicals from the ground, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water. States report that nonpoint source pollution is the leading remaining cause of water pollution.[14]

Because the sources of nonpoint source pollution are widely dispersed and varied, cookie-cutter approaches to managing the problem that do not address the unique needs of a particular area are likely to be ineffective. What is needed are site-specific management approaches—which can range from creating ponds near construction sites to corralling polluted runoff to placing gravel and sand in areas in order to sift out pollutants.[15] Researchers at Virginia Tech have recently developed a software program to help manage nonpoint source pollution that takes into account dozens of factors, including slope, soil type, and other site-specific criteria, to develop a best practice approach to managing stormwater runoff in a particular location.[16] The software program uses computer models to evaluate the efficiency of various management plans. It is currently undergoing a trial run and will soon be available free of charge to watershed management experts everywhere.

Scientists elsewhere are using IT to figure out how best to reduce and manage the runoff from urban soil that pollutes nearby streams and rivers. Researchers in Scotland, for example, have been experimenting with Web-based GIS decision management tools to better figure out what to do with contaminated urban soil. The Scottish researchers' application spatially models data about soil conditions and helps decisionmakers better understand the available management options and relative impacts.[17] Moreover, the tool offers Web-based transparency of the decisionmaking process for soil management, thereby enabling concerned local residents, nongovernmental organizations advocating for urban environmental quality, and others to gain access both to the details of decisions that affect the quality of their environment and to the details of the underlying decisionmaking process. With better information, citizens can more effectively oversee the policymakers who represent them, thereby ensuring that government is more responsive on water pollution and other environmental matters.

Pesticides, fertilizers, and herbicides are a fundamental component of the large-scale modern farming that feeds much of the world because they support increased crop yields, but with agriculture accounting for 38 percent of worldwide land use,[18] agricultural runoff (surface water containing these and other contaminants) has emerged as a primary threat to watersheds around the world. IT-enabled technology, though not a panacea, has the potential to diminish the problem of nonpoint source pollution from agricultural runoff.

An important area of IT-enabled technological innovation to reduce water pollution caused by agricultural runoff is the use of smart application processes to apply fertilizers, pesticides, and herbicides. GPS-enabled tractors with sensors, for example, can ensure that farmers apply fertilizers more efficiently and do not fertilize the same places more than once. In addition, researchers are experimenting with smart application processes that can reduce the need for herbicides. Using herbicides is an imprecise method of fighting weeds because both crops and weeds are doused in chemicals. Tractor-mounted smart sprayers outfitted with vision sensors can automatically identify weeds and deliver herbicide in tailored amounts.[19] Targeted applications of herbicide can reduce overall herbicide usage, saving farmers money and reducing the impact of such products on the soil and surrounding bodies of water.

Another technology being developed by Danish scientists to help reduce agricultural runoff is a remote-controlled robot, called a "Hortibot." Hortibot relies on visual sensing to navigate crop rows with relative autonomy—even turning at the end of each row to proceed down the next—and will soon be outfitted with either precision herbicide-spraying or manual weed-removal tools.[20] Although the Hortibot is still costly—purchasing one will set a farmer back about $55,000—advanced robotic applications such as the Hortibot could dramatically reduce herbicide use by going back to the old fashioned way of managing weeds—picking them by hand, only in this case, by a robot's hand.

Advanced robotic applications such as the Hortibot could dramatically reduce herbicide use by going back to the old-fashioned way of managing weeds—picking them by hand.

Understanding Aquatic Ecosystems

Scientists are turning to a host of IT-enabled technologies, including sensor networks and sophisticated computer models to improve their understanding of complex aquatic environments and pollution. The Beacon

Institute, IBM, and Rensselaer Polytechnic Institute scientists are participating in an innovative project that is installing sensors along the entire Hudson River in New York. These sensors, many of which will be suspended from buoys, can transmit data wirelessly to shore and will reveal for scientists a virtual river, including information about pollution levels and the state of marine life.[21] The researchers also plan to deploy a solar-powered underwater robot armed with sensors in the Hudson River to augment the data collection.

With a more comprehensive understanding of the entire ecosystem of the Hudson River, scientists will be better able to gauge the environmental impacts of pollution and be better able to detect in real time new pollution sources, making it more likely that the sources can be stopped in a timely manner. Years ago, when many of us were children, we had no qualms about jumping into a river, stream, or ocean to go swimming. As parents today, we might caution our children against jumping in some places because we simply do not know how safe the water is. In the foreseeable future, there might be IT-enabled sensor systems on all kinds of bodies of water that might be accessed just by pressing a few buttons on a cell phone. Even today groups like Earth911 offer online maps that display current beach information such as water quality and weather.[22]

Similar projects have endeavored to map other aquatic ecosystems. In Rhode Island, for example, the MapCoast and BayMap Partnerships are using sophisticated imaging technology to learn about plants and animals that live on the floor of Narragansett Bay. They are using advanced imaging tools to construct digital terrain models that are designed to understand better how bottom-dwelling organisms—a fundamental piece of the ecosystem that supports life throughout the Narragansett Bay—respond to water pollution.[23] Even more ambitiously, MIT's Darwin Project has developed a computer model that mimics 10 years of evolution of an array of underwater microscopic plants, such as phytoplankton—all governed virtually by the rules of natural selection. The project is novel because it more accurately reflects the messy complexity of life and evolution than previous efforts, and as a result its "evolution" processes has produced species of phytoplankton very similar to those that have actually evolved in the real world.

Understanding the complex processes that govern ocean microbes is important in a world in which humans are adding carbon dioxide to the atmosphere because ocean microbes help to regulate atmospheric carbon dioxide and produce half of the atmosphere's oxygen.[24] The IT tools required for such complex analysis are still relatively new, but scientists' understanding of such interactions is growing quickly as the models become more sophisticated.

MIT's Darwin Project has developed a computer model that mimics 10 years of evolution of an array of underwater microscopic plants—all governed virtually by the rules of natural selection.

Facilitating Recycling

Only a few years ago, recycling required extensive sifting and sorting to separate the different types of recyclable materials before setting them on the curb. Now thanks to a new technology called single-stream recycling that relies on automatic sorting machines underpinned by advanced IT, more and more businesses and homeowners today can recycle their bottles, cans, and newspapers by throwing them in a single bin for collection without giving the matter another thought.

Automatic sorting machines improve the efficiency and speed with which recycled material can be sorted. Such machines employ conveyor belts to carry recycled materials past devices that identify and sort them. Magnets pull metal objects out of the stream into one bin, while optical sensors identify paper and plastics, then eject them by targeted jets of air into another bin. Computers rely on the frequency of reflected infrared light that indicate the type of plastic of a particular object for separating plastics by material. The automated process operates with accuracy rates generally over 90 percent.[25]

Single-stream recycling made possible by the automated sorting machines encourages residential recycling by simplifying the process for households.

In fact, recycling rates have increased by almost 30 percent for people who live in areas where the single-stream recycling system has been implemented.[26] And the ranks of single-stream recyclers are growing both in the United States and around the world. Waste Management Recycle America already operates 27 single-stream recycling plants in the United States.[27] Titech, a leading Norwegian manufacturer of the sorting machinery, has delivered over 800 of them to Australia, Korea, Japan, countries in Europe, and the United States, with more on the way.[28]

People who are highly motivated to do the "right" thing already engage in recycling, but more people would recycle if they could receive a more direct benefit for recycling. IT already underpins the deposit refund incentives that encourage people to return bottles and cans. The machines typically found at supermarkets that accept bottles and cans in exchange for deposit refunds rely heavily on IT-driven identification systems to sort and collect deposited bottles and cans with high accuracy.

But now the city of Philadelphia is taking things a bit further. It is using radio-frequency identification (RFID) tags on recycle bins to track the amount of recycled material that households leave out for collection, rewarding consumers for their participation with coupons redeemable at local businesses. Philadelphia's system uses scales mounted on the recycling truck's forks to weigh each household's recyclables; and computer software on the truck communicates with each household trash bin's individual RFID tag, tracking the amount of recycling for each household in an online database. Consumers, in turn, can track online the money they accrue in "recycle dollars" for their efforts. Since the implementation of Philadelphia's incentive program, recycling rates have skyrocketed, reaching 90 percent.[29]

Through a handful of applications, IT makes recycling easier for consumers while boosting the efficiency of the process and utility of recycled materials.

Preserving Biodiversity: Resource Conservation and Saving Endangered Species

No less important than controlling the pollution and waste that humans produce is the task of ensuring that humans make responsible use of the finite resources that they consume. To obtain these critical resources, humans rely on the world's forests, bodies of fresh water, and mineral deposits, among others. Unfortunately, however, our demands can threaten these delicate ecosystems, depleting precious resources, and endangering the natural biodiversity of these areas.

As global population growth and economic growth place an increasing strain on the world's resources, IT has become a critical tool in efforts to conserve them. Thanks to IT, there have been dramatic improvements in data-processing, satellite-tracking, and remote-sensing technologies that permit improved monitoring and management of the world's increasingly threatened ecosystems and endangered species. IT is also making it possible for conservationists to communicate and work together more easily.

Protecting Sensitive Environmental Areas

Protecting sensitive environmental areas from damage caused by humans requires first and foremost information—and, ideally, information in near real time. The need for information is nowhere more critical than in preserving rainforests, which are home to over 50 percent of the world's plants and animals.

By definition, rainforests are a renewable resource. But old growth forests, supported by mature trees and often home to a vast array of flora and fauna, take many—even hundreds—of years to regenerate fully after being cleared. Rainforests are the most conspicuous example of such old growth forests. With their diversity of life, rainforests are a treasure in their own right, not to mention that such diversity offers the promise of new cures for life-threatening diseases. Yet by some estimates, 37 plant, animal, and insect species become extinct each day due to rainforest deforestation. Because of deforestation, rainforests now cover less than 2 percent of the Earth's surface, and tropical rainforests are particularly under threat, having declined in total area from their original 6 million square miles worldwide to the current 2.6 million.[30]

Using geographic information systems (GIS), remote-sensing, and satellite-tracking technology, governments and nongovernmental organizations are able to monitor closely the existing rainforests remotely and, as a result, can more efficiently and effectively ensure their preservation. Scientists at Woods Hole Research Center in Falmouth, Massachusetts, for example, are working with the Japanese Space Agency (JAXA) to generate advanced satellite images of the Amazon rainforests at unprecedented clarity (25-meter resolution).[31] These frequently updated "snapshots" reveal much about the current state of the Amazon rainforests and where land has been cleared. Thus, they provide rainforest monitoring programs a critical tool for enforcing preservation agreements and fighting deforestation.[32] With more accurate and timely rainforest monitoring comes greater leverage for conservation efforts.

Rainforest advocates in the Amazon have also enlisted the help of local tribes to protect large swaths of rainforest. Members of local tribes, armed with handheld GPS units provided by the Virginia-based Amazon Conservation Team, have been mapping their lands by foot, using the technology to create electronic maps of land to cordon off from development and the accompanying pollution that it brings.[33] With Internet-accessible computers, the tribes monitor Google Earth's satellite images of their lands, identifying possible incursions for further investigation and informing governments of such activity.[34] IT is similarly supporting efforts to gain a better understanding of Central African rainforests and the logging that threatens their preservation. Woods Hole researchers have used satellite images dating from 1976 to 2003 to understand how logging has affected the forests over time. The goal is to translate this understanding into working with policymakers to develop better planning for future logging.[35]

Beyond rainforests in the Amazon and elsewhere, forest preserves in the developed world require vigilance to prevent disruptive human activities such as illegal hunting and waste dumping. Traditionally, preventing these disruptive human activities has required the stewardship of forest management staff—an expensive, and not always effective, proposition. A project in northern Maine has recently demonstrated the viability and cost-effectiveness of using aerial and satellite monitoring to monitor the 760,000-acre Pingree Easement as an alternative.[36] An IT-enabled surveillance system such as this dramatically reduces the need for forestry staff because field trips into the forest preserve (now facilitated by handheld GPS units) become necessary only when a problem is identified in high-resolution satellite and aerial photography. With its aerial and satellite surveillance system, the Pingree Easement's yearly management costs have dropped to below $70,000—an amount much less than the estimated cost of several hundred thousand dollars for traditional management practices.[37]

Uniting Conservationists

Movements to preserve threatened natural areas enjoy popular support among legions of environmentally conscious citizens and outdoor enthusiasts, and IT plays an important role in these movements in a way that has nothing at all to do with actual resource management—by uniting people who support conservation. As noted elsewhere in this report, the Internet facilitates communication between people with shared interests. People in conservation movement fall into this category. Thus, for example, groups like the Nature Conservancy rely heavily on the Internet to reach their base of members and donors, informing them of important conservation developments and soliciting contributions.

Many conservation problems, like rainforests, are geographically distant from the majority of the people who care about them. Internet-delivered images, video, and interactive applications can vividly communicate information about such problems to people who are far away. A Web video showing a seal covered in oil in the wake of a spill, for example, or a blog about a situation can be far more compelling and effective than a traditional media report. In addition, IT-enabled technology can be used to tailor conservation groups' messages to make them relevant to particular individuals. As an example, ilovemountains.org, an organization committed to eliminating the practice of mountaintop strip mining in Appalachia, prompts site visitors to enter their zipcode to determine whether their electricity relies on Appalachian coal removed taken from mountaintop mines (if you live in the United States, it probably does). Through the website's Google Maps interface, visitors can learn about their connection to the practice, find out more about the mountaintop mines that supply their electric utility, and learn how to take action to end the mining. This is but one example of how the Internet is facilitating and promoting individual and collective action in the environmental movement.

Saving Threatened Species

Scientists and governments are turning to advanced IT tools to learn about and preserve the habitats of threatened species, as well as to combat animal trafficking and poaching, which, despite their general prohibition, threaten the extinction of many species around the world.

With human-driven development continuously encroaching on remaining wildlife habitats, the threats to animal populations are often myriad and growing. Wildlife experts have only recently been able to apply advanced IT tools for tracking animals in order to understand more precisely the habitat needs of mammals, birds, and various other threatened species. In the case of one critically endangered species, spotted owls, the birds have been fitted with tiny radio transmitters that allow researchers to track their movements by triangulating the signals. By combining this information with GPS readings, researchers are able to track spotted owl locations in real time. From compiling these data over time, researchers then construct maps of each unique owl's home range.[38] As a result, they know the habitat that needs protection from human incursion.

Similarly, the World Wildlife Fund has begun tracking peccaries (tusked pig-like animals) in the Amazon using RFID tags clipped to the animals' ears.[39] The organization is using the findings to inform its advocacy for wildlife habitat needs in the Amazon region. Monitoring endangered species, especially at birth, can be key to their survival in the wild, yet monitoring can also be cumbersome and risky to the wildlife. To solve the problem, the U.S. National Aviary uses webcams to monitor peregrine falcon nests; feeds are then uploaded onto its website, where experts can remotely observer the birds.[40]

Some researchers have used IT to help track the migration of birds. Monitoring bird flight is crucial in order to preserve the wildlife habitats vital for bird migration. Before IT-enabled tracking devices were developed, processes to track bird migration were costly and inaccurate.[41] Currently, one bird migration project uses thousands of tracking devices on North American rooftops connected to home computers to capture bird sounds, which scientists can then use to identify bird species, numbers, and flight characteristics. Another project currently under development is planning to attach tiny wireless devices to small birds called prothonotary warblers to track their migratory patterns using cell phone towers. A better understanding of prothonotary warblers' migration patterns, say the researchers at Oregon State University responsible for the project, will yield insights into the birds' population declines.[42]

Tracking of a different sort is underway in northern Canada, where researchers are attempting to gauge the decline of the northern polar bear population. Wildtrack, an organization devoted to tracking polar bear population levels, has developed a database for tracking polar bears by digital photographs of their footprints, relying on computer algorithms that match anatomical characteristics unique to each animal.[43] From their observations and matching analysis, researchers can learn about the size of a polar bear population in a particular area and each animal's unique movements.

Anti-animal-trafficking activists in Zimbabwe use the same technology to collect and aggregate digital photographs of black rhino footprints and use GPS to plot the location of each snapshot. Knowing that the animals' footprints last only about 24 hours, they are able to create a precise map of each black rhino's movements.[44]

Animal trafficking involves the illegal trade of rare animals for private collectors, biopiracy, pet animals, and poached body parts. The trade is widespread in places like Brazil, where an estimated 38 million animals are poached every year, and over 600 species are now threatened by extinction.[45] Though the illicit trade has long operated in the shadows, that is now changing thanks to the Internet. One Brazilian group, RENCTAS, has used the Internet to raise public awareness, much the way other nongovernmental organizations have worked in other areas, but the group has now taken its Internet operation a step further. Rather than simply reaching out to the constituency of mobilized supporters, RENCTAS actively engages in the fight against animal traffickers, soliciting anonymous tips to protect informants, and scouring websites, posing as potential buyers. The group turns over its information to the authorities to act on it.[46] Because animal traffickers are often organized and dangerous, the Internet's anonymity is crucial in the organization's efforts to fight them.

Poaching is another problem that threatens animal species. Despite laws protecting species like elephants and tigers, the black market ensures the continued poaching of these animals for their ivory tusks and pelts. Like the destruction of the natural environment, animal poaching is in part an information failure. Animal poachers can get in and out, doing their damage, before officials know what happened. Now IT-enabled tools are helping authorities catch up with the criminals. Scientists at the University of Washington, for example, have geographically mapped the genetic variations of African elephant population.[47] By analyzing genetic evidence gleaned from seized tusk shipments, the scientists are able to track the origin of the elephants—a major step in international investigations of the banned elephant ivory trade. The University of Washington researchers and several African governments hope to expand the genetic tracing, which relies on IT-enabled analysis, to other threatened species, including tigers. But genetic analysis is not only useful for combating poachers. A better understanding of the locations where closely related populations of a certain species live gives scientists a window into natural migratory patterns, and how best to restore them.

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11. Energy

With skyrocketing gas prices, growing concerns about the impact of fossil fuel emissions on global warming, and turmoil in the Middle East, achieving reductions in both energy consumption and carbon emissions has become the subject of renewed focus. And because so much of the energy in the United States comes from fossil fuels like coal and oil, reducing energy usage and carbon emissions are intimately tied.

Not much attention has been paid to the role of information technology (IT) in reducing carbon emissions; in fact, some people even see IT as contributing to the problem because the IT infrastructure and devices themselves consume electricity. Yet by transforming all sectors of the economy and society—from e-commerce and just-in-time manufacturing to telecommuting and clean alternative energy technologies—IT is allowing the U.S. economy to become more energy efficient and less carbon intensive. IT is doing that by:

- letting many energy-intensive physical activities be substituted for more energy-efficient digital activities
- enabling individuals and organizations to adopt more energy-efficient practices and processes
- rewriting the rules of electricity production, distribution, and consumption
- reducing energy use in the IT sector itself

The bottom line is that the transformation to a more digital and information-driven economy will be a key factor in reducing energy usage and carbon emissions in the United States and elsewhere.

Substituting Energy-Efficient Digital Connections for Physical Travel

Travel serves two main purposes: transporting people and goods for physical activities (e.g., driving to mountains to go hiking) and transporting people for information activities (e.g., flying across the nation to attend a meeting). Although IT cannot substitute for the first kind of travel, it can and is substituting for the second. In other words, IT is letting people reduce the number of trips they take primarily to engage in information processing and exchange.

Indeed, IT is at the heart of many solutions that promise to reduce the number of miles traveled in the transportation sector. As discussed below, IT can cut energy usage in the transportation sector by allowing office workers to telecommute or companies to hold virtual meetings or reducing the need to transport some goods by transforming them into bits that can be moved through energy-efficient telecommunications networks. Given that the transportation sector accounts for a significant share of energy use in most nations—for example, 29 percent in the United States in 2007—the opportunities that IT offers to reduce physical travel are very important.[1]

Telework

In the old economy, when most things were on paper, when phones were analog, and when many fewer jobs involved information tasks, it was difficult for most workers to work remotely. Now armed with just a computer, a broadband connection, and a smart Internet protocol phone, home workers can perform all the functions that they would in the typical office environment.

In fact, IT has become such an integral part of the office environment today that physical location is less important than ever before. Home-based workers can keep in touch via e-mail and instant messaging applications. They can connect easily and securely to work servers using virtual private networks. They can collaborate on documents with colleagues with a wide array of software programs, and can attend meetings virtually through teleconferencing or videoconferencing. Smart office phones can automatically route office calls to the home or alert workers by e-mail when they have a voicemail message. And with the proliferation of high-speed broadband, the connection between a home computer and the office is now nearly as fast as the connection between an office computer and the office server.

Much of the evidence on the productivity of telecommuting is anecdotal or from self-reported data at this point, but there are good reasons to believe that telecommuting does let people in many jobs work more productively.[2] First, many people report that they can get more done with fewer interruptions at home. Second, telecommuting allows employees to work when personal or family needs might other-

One study estimates that in 2007 the telecommuters in the United States saved 840 million gallons of gasoline and reduced carbon emissions by almost 14 million tons.

wise force them to be absent from the office.[3] Finally, telecommuting frees employees from, on average, almost an hour of commuting each day. If any of this time is put toward working, it translates into greater output.

As a result of such considerations, many organizations are now encouraging their employees to telework. One is the retailer Best Buy. By relying on IT (broadband, mobile e-mail, faxes, etc.), Best Buy was able to give a large share of workers at its corporate headquarters the option of more flexible working hours, including working at home; the workers' output increased by 35 percent. Many of airline Jet Blue's reservation agents also work from home, using a personal computer (PC) and broadband telecommunications connections. And in other organizations, more and more corporate employees are "going Bedouin," with as many as 40 percent of all employees not in the office on any given day.[4]

By 2004, the overall number of workers in the United States who spend any time working from home—including both part-time telecommuters who work at home as little as one day a year and individuals who work at home full time—had grown to 44.4 million.[5] The vast majority of workers in the United States who spend any time working from home engage in part-time telecommuting. At the U.S. Patent and Trademark Office (PTO), for example, a part-time telecommuting program was introduced over 10 years ago. By 2007, there were 220 trademark examiners and 600 patent examiners participating in the program—and plans to add 500 teleworking patent examiners in each of the next five years.[6] In addition to saving commuting time and energy, the PTO's part-time teleworking program saves office space. Participating employees spend approximately one day per week in the PTO office, where a limited number of desks are designated as available for telecommuters. In 2006 and 2007, as a result of its teleworking program, the PTO was able to hire 1,200 new patent examiners without having to lease more office space.[7]

In 2006, thanks to advances in IT, telecommuting and at-home work, about 5.4 million people—3.9 percent of the U.S. workforce—regularly worked from home.[8] The potential of teleworking to expand is tremendous, given that, according to one estimate, about 20 percent of the U.S. workforce engages in work that is eligible for at least part-time telecommuting.[9] Moreover, if some regions of the United States move to implement congestion pricing—IT-enabled automatic tolling systems on roads that are congested, such as those used in London and Stockholm—that, too, would spur the expansion of telecommuting.

The impact of transportation on the environment is substantial. In the United Kingdom, for example, one-quarter of the country's carbon dioxide emissions come from transport.[10] By allowing people to work effectively from a distance and by providing the tools to make transportation more efficient, IT is reducing energy use and carbon emissions in the transportation sector. In fact, one study estimated that in 2007 the telecommuters in the United States saved 840 million gallons of gasoline and reduced carbon emissions by almost 14 million tons.[11] With private vehicles responsible, by one account, for between 30 and 50 percent of greenhouse gas emissions, the potential benefits from widespread telecommuting are dramatic indeed.[12]

In addition, because telecommuters' reduced travel comes largely at peak travel times when traffic congestion is most severe—"rush hour"—the reduced traffic allows the remaining cars on the road to flow more freely, thereby saving additional energy as a result. Fewer cars on the roads means less gridlock, so even the remaining cars pollute less (because each car pollutes more when stuck in traffic).[13] The benefits from reduced congestion are substantial, given that congestion alone wasted 2.9 billion gallons of fuel in 2005 in the United States—an increase of 480 percent from 1982, when congestion accounted for 500 million gallons of fuel.[14] As traffic congestion continues to worsen, telecommuting offers a remedy that few other traffic solutions can match: the prospect of actually taking vehicles off the road by eliminating the need to travel altogether.

In addition to reducing travel, telecommuting saves energy by reducing the amount of office space the economy needs to build and heat and cool. Like the PTO, many corporations have been able to reduce the amount of office space they occupy as more workers either telecommute full time or engage in "office hoteling," in which employees do not have dedicated offices, and instead reserve flexible space when needed. Under Sun Microsystems's Open

Work program, for example, employees can work from almost any location where there is an Internet connection. Currently, 19,000 Sun employees, 56 percent of the total employee population, are participating in the flexible telework program. Fifty percent of Sun's employees telecommute or work from a flexible office part time, and 6 percent do so full time. As a result, Sun has realized office space savings equivalent to $387 million dollars.[15] One study estimates that, if a predicted additional 10 percent of the U.S. workforce takes up telecommuting within the next 10 years, the United States would need 3.3 billion square feet less of office space. Forgoing the construction of this large amount of space would save 28.1 billion tons of greenhouse gas emissions.[16]

Though it might seem fairly straightforward that giving up a commute would naturally result in less driving and diminished pollution as a result, some analysts have argued that the reality is more complex. They note, for example, that some telecommuters may take advantage of their freedom to live in a more remote area than they might otherwise, which requires longer travel for tasks unrelated to work, such as buying groceries, for example. In other words, if telecommuting frees us from the ties of city living, it might actually encourage us to live more energy-intensive lives that actually result in increased pollution. Moreover, the energy savings that result from the construction and operation of less office space as more people work from home may be offset by increased home energy demands caused when home workers use computers and air conditioning that might otherwise remain dormant during the day.

Such arguments seem to be countered by Walls and Safirova's recent review of the literature, which found that telecommuting reduces commuting mileage and does not appear to be associated with a significant increase in the amount of noncommuting mileage traveled. In fact, telecommuting reduced daily vehicle travel by 53 percent to 77 percent.[17] An analysis of the substitution and environmental effects of telework, teleconferencing, and telemedicine in Sweden similarly found that if these three substitutes were used to their utmost potential, overall travel in Sweden could be reduced by one-third.[18]

More research is needed to better understand and compare the energy impact of having people work in a home environment versus having people work in an office. It is plausible that the increase in home energy use is outweighed by the energy savings from the need for less office space, and in turn, less construction and office energy use. With buildings accounting for 39 percent of primary energy use in the United States,[19] the benefits from constructing fewer offices would be substantial.

Sun Microsystems' Open Work program offers an example of the environmental and cost-saving possibilities that can result when firms take advantage of teleworking. A recent report on the program analyzed whether telework reduces Sun's carbon footprint or simply transfers energy costs to employees working at home. By comparing home and work energy use of more than 100 Sun employees, the study concluded that teleworking enables employees to save money, reduce their carbon footprint, and be more efficient employees. Employees working at home 2.5 days a week saved $1,700 per year on gasoline and car repairs. Commuting represented 98 percent of each employee's carbon footprint for work; by working from home 2.5 days a week, employees reduced their energy use by the equivalent of 5,400 kilowatt-hours annually. And by not commuting, employees saved an average of 2.5 work weeks a year, making more efficient use of their time.[20]

With higher gas prices, the widespread deployment of broadband Internet connections, and the advent of next-generation broadband applications like videoconferencing, there can be little doubt that teleworking will continue to grow substantially in the years to come. Given that just over half of the households in the United States have broadband connections at home—though, to be sure, the numbers are higher among office workers—there is certainly room for growth, and with traffic congestion worsening, telework is becoming an ever more attractive option.

Videoconferencing

Beyond making all or some trips to the office obsolete for some workers, IT is helping to make unnecessary many business trips that currently require expensive and energy-intensive air travel. Although companies have long made use of videoconferencing technology, its quality has until recently been relatively poor, with high levels of latency, poor picture and sometimes sound quality, and limited screen size. Thus, a videoconference was more like a slightly better phone call than a slightly worse in-person meeting. Not surprisingly, business travel has continued to grow, accounting for 25 percent of all domestic trips in the United States.[21]

IT has only recently begun to change this, as broadband connections have become fast enough and computing equipment powerful enough to support more robust virtual videoconferencing technology. Technologies such as those offered by Cisco and HP allow for real-time virtual meetings that begin to create adequate substitutes for real face-to-face interaction, particularly when considering the time and cost savings of not having to hop on a plane and stay in a hotel. These technologies offer high-definition audio and video that even allow participants to communicate with body language, making virtual meetings almost as lifelike as face-to-face meetings.

The potential for energy savings is also significant. One study has estimated that if Europeans substituted videoconferencing for 20 percent of air travel, the European Union could reduce carbon dioxide emissions by 22 million tons annually.[22] Although it is difficult to predict how using telepresence technology and other collaborative and mobile technologies might reduce travel, one estimate by Cisco suggests that it might eventually reduce overall air travel by 10 percent to 25 percent from what it would be otherwise.[23] Right now, the costs for the devices and telecommunications technologies are still relatively high. The costs are expected to decline, though, in which case such technologies will become more affordable for more organizations and applications. Even so, it would be unrealistic to expect videoconferencing to replace the need for business travel altogether because not every important decision on a business trip is made in a meeting room. Nevertheless, it appears that some routine business travel could be eliminated, thereby cutting costs, reducing energy use, and reducing carbon emissions.

Dematerialization: Transforming Atoms into Bits

By allowing the widespread production, transmission, and consumption of virtual products—replacing bits for atoms—IT is paving the way to a more sustainable society. The IT-enabled "dematerialization" of the economy—in which atoms (e.g., letters written on paper) are increasingly replaced with bits (e.g., e-mail)—is leading to energy savings not just from reduced transportation, but also from reduced production of material goods.

If Europeans substituted videoconferencing for 20 percent of air travel, the European Union could reduce carbon dioxide emissions by 22 million tons annually.

Take movies and music, for example. For most people, watching a movie at home has traditionally required getting into a car and driving to the movie store. But with the emergence of high-speed broadband networks and much easier-to-use home video network systems, movies are beginning to be offered digitally over the Internet. Likewise, instead of getting in a car to drive to the mall to buy a music compact disc (CD), increasingly consumers are buying their music online and downloading it to a digital music device. This not only eliminates the trip to the store to get the disk, it eliminates shipping from the CD manufacturer to the wholesaler and the retailer, and saves all the energy used in producing the plastic and the disk. Online music sales are growing rapidly, too. Apple's iTunes, the leading online music store, recently became the second most popular music retailer in the United States, behind Wal-Mart, the country's largest retail firm. Apple has sold more than 4 billion songs without shipping a single physical CD (or the accompanying plastic packaging) or erecting a single iTunes retail store.[24] Fuhr and Pociask have estimated that eliminating the production of CDs and their plastic cases in the United States alone could save 42 million gallons of oil per year while reducing greenhouse gas emissions by half a million tons.[25]

But digital movies and music are just one manifestation of the larger phenomenon of dematerialization. Paper is a prime example, as the IT revolution has digitized many tasks that used to require paper, including letters, newspapers, office work, and even books, with considerable energy savings and environmental benefits. Paper manufacturing is an extremely energy-intensive process, requiring about 3,405 kilowatt-hours of energy to produce 100 tons of paper.[26] Thus, reading the news on a personal digital assistant (PDA) releases 32 times to 140 times less carbon dioxide than reading the news in a newspaper.[27] With the advent of Web-based news, newspaper circulation has declined on average 1.7 percent a year in the United States, and Fuhr and Pociask have estimated that this decline in newspaper circulation has already prevented the release of 7.9 millions tons of greenhouse gases from paper news production processes.[28]

Similarly, instead of relying on paper mail, consumers and businesses have increasingly been turning to the Internet to do their banking, pay bills, file taxes, and generally communicate. As a result, the use of first-class mail in the United States has been on the decline, with the number of first-class mail pieces dropping from 103.5 billion pieces in 2002 to 97.6 billion pieces in 2006, saving 184,000 tons of paper—not to mention saving the energy that would have gone to manufacture all this paper, an estimated 7.4 million British thermal units (BTUs) annually.[29] IT has had a similar impact on the use of paper checks. There is little wonder that banks have embraced the technology, given that processing a check costs banks approximately $1.40 compared to just 8 cents for processing an electronic bill payment. The result has been a dramatic decline in the use of paper checks, and the accompanying energy required for their printing and processing. According to the U.S. Federal Reserve, check-writing in the United States has declined in recent years, going from 49.5 billion checks paid in 1995 to 36.7 billion checks in 2003.[30]

Enabling More Energy-Efficient Practices and Processes

Business has driven the IT revolution by deploying new technologies strategically in order to reinvent and streamline practices for the sake of productivity gains. IT that drives increased efficiency in business frequently leads to more energy efficiency because waste in business often equates to waste of energy. As a result of the deployment of IT technologies to enable more energy-efficient practices and processes—including more efficient logistics and travel and e-commerce—the American economy has become considerably less energy-intensive over the last 15 years.

On-board computers that allow managers to better coordinate trucks and loads boost capacity utilization 3.3 percent and save $16 billion annually in the $500 billion trucking industry.

More Efficient Logistics and Travel

IT-enabled advances in manufacturing and supply chain technologies help firms better track inventory and engage in just-in-time production, thereby eliminating the production of unnecessary inventory, with energy savings at every step of the production and supply chain. The result has been energy savings from less manufacturing and warehouse infrastructure (resulting in less construction), as well as from the decreased need for transportation. The projected monetary savings from eliminating unnecessary inventory run in the hundreds of billions of dollars—between $250 and $350 billion according to one 1999 study.[31] Although no analysis of the energy savings has been conducted, the energy savings from reducing unnecessary inventory are likely to be correspondingly large.

In addition, IT is allowing the transportation sector to be more efficient by increasing capacity. Airlines, for example, use IT to better schedule flights and to raise seat utilization, allowing them to fly fewer flights, saving fuel and money. Now airlines can advertise and sell e-fares online one or two weeks before a flight departs, filling up otherwise underbooked flights with customers willing to fly with flexible schedules and pay lower prices. This capability is particularly important in ensuring that scheduled departures are as full as possible because airlines receive no revenue from empty seats and the increased weight of each additional passenger means little in terms of fuel use. Although we passengers might not like flying in full planes, the end result is that airline fares and energy consumption are lower.

This same phenomenon is occurring in freight movement. Companies are also relying heavily on IT to boost the efficiency of their transportation fleets. United Parcel Service (UPS), for example, uses software that allows the company to optimize its truck delivery routes, resulting in significant fuel savings. In 2006, UPS reduced truck travel by 28.5 million miles with the software.[32] Because of difficulty in predicting demand for hauling, transportation companies' equipment is often underutilized. Trucks, for example, may be fully loaded for delivery but then have to make the return trip partially or completely empty. Indeed, about one-fifth of trucks at any one time are "transporting air."[33]

With global positioning system (GPS) devices, cell phones, and wirelessly connected computers, truck drivers and dispatchers can now more easily find loads to pick up for return deliveries, boosting fleet efficiency and cutting the overall number of trips.[34] By using IT to coordinate schedules, for example, two companies, Fort James Paper and General Mills, were able to give their scheduled runs to a single carrier that dedicated trucks to the business, leading to savings of $731,000 a year.[35] The Internet enables this kind of demand aggregation. Websites like Getloaded.com act as a matching service, preventing excess capacity from going to waste by connecting trailers that would otherwise be traveling empty with loads that need to go to the same destination. One study found on-board computers that allow managers to better coordinate trucks and loads boosted capacity utilization 3.3 percent and saved $16 billion annually in the $500 billion trucking industry.[36]

Beyond making freight travel more efficient, IT is making individual travel more efficient. IT is also making vehicles smarter and more efficient in a number of ways. One everyday example of this phenomenon are the GPS-driven navigation tools that help drivers find the fastest, most efficient route for any given trip. These devices have become increasingly sophisticated, with newer models combining GPS navigation with continuously updated traffic flow information to automatically optimize recommended routes. The European Commission's Intelligent Car Initiative envisions a more fuel efficient car owing to a range of technological innovations that encourage more efficient driving behavior and better vehicle maintenance, including tire pressure monitoring systems (because underinflated tires decrease gas mileage).[37]

E-Commerce

E-commerce, one of the most visible manifestations of the IT revolution, yields significant energy savings. New e-commerce-enabled business practices like Amazon.com's centralized warehousing are actually less damaging to the environment than traditional bricks-and-mortar retail operations even though such practices result in increased shipping. Hendrickson and Matthews, using the U.S. Department of Defense (DOD) as a case study, found that centralizing warehouses greatly reduces environmental impacts; they also found that centralizing all 286 DOD warehouses for spare parts into 19 major warehouses would render a net benefit economically and environmentally even if twice as much trucking and shipping were used as a result of lower warehousing costs.[38]

E-commerce and centralized warehousing result in even greater savings in the retail environment, primarily because most retail shoppers get in the car and drive to a store, using considerable amounts of energy unnecessarily. Instead of driving from store to store, consumers can now compare items and prices with the click of a button. When products and consumers meet virtually rather than face-to-face, the energy savings are considerable. Indeed, in an analysis of online booksellers, Matthews and Hendrickson find that reduced automobile trips are an important factor in giving the environmental and energy edge to e-commerce over traditional retail, despite the increased packaging required, along with the authors' assumption that all e-commerce book orders are shipped at least partly via air freight.[39]

Centralized warehousing is a critical IT-driven innovation, especially in the book industry, given that approximately 35 percent of best-selling books are left over and returned from retail stores as "remainders"—a practice eliminated altogether in e-commerce. The energy involved in selling $100 of books is 14 times more for a traditional superstore than for an online bookseller.[40] And Romm documents how a 20-mile round trip to the mall to purchase two five- pound products consumes about a gallon of gasoline, while shipping the packages 1,000 miles by truck consumes only 0.1 gallon of gasoline. By allowing for significant changes to the way that we shop, e-commerce is dramatically reducing energy consumption.

Rewriting the Rules of Electricity Production, Distribution, and Consumption

With coal power plants responsible for nearly 40 percent of electricity production worldwide,[41] electricity generation is responsible for a significant share of global carbon emissions. And the problem is not limited to the most industrialized countries of the world because China is erecting new coal power plants at a pace of one per week.

Fortunately, IT is rewriting the rules of electricity production, distribution, and consumption. In response to growing concerns about global warming and energy independence, energy efficiency and alternative energy sources have become the subject of renewed focus. New energy production technologies, including wind and solar power, rely heavily on IT for their design and operation. IT is also revolutionizing the way that we distribute and consume energy through innovations such as the smart grid, also resulting in considerable energy savings.

New Energy Production Technologies

Renewable energy sources constitute a small, albeit growing, segment of the power- generation sector. Design improvements made possible by IT continue to drive improved performance and efficiency, in the process making renewable energy technologies increasingly competitive with traditional, and dirtier, energy sources. Two such energy sources are wind and solar power.

Wind turbines have come a long way since the days of the simple windmill. Manufacturers like General Electric now design advanced wind turbines that rely on IT to automatically adjust the blade angle (pitch) for optimal efficiency in a variety of conditions and wind speeds.[42] Advanced electronics also manage the flow of electricity between these turbines and the electricity grid, ensuring integration with the grid, even under intermittent wind conditions.[43]

Apart from the computer technology contained in wind turbines, IT also underpins the advanced modeling that has become a critical part of the wind energy industry. Companies like 3Tier use wind modeling to identify the best sites for wind farms, where wind turbines will work most efficiently. Wind energy companies also rely on advanced weather modeling to anticipate future conditions and in turn predict production levels.

IT is no less important to solar power generation, a technology with zero emissions and minimal operating costs. In fact, the photovoltaics used in solar cells generally rely on silicon, and technology manufacturers such as Applied Materials have simply retooled their semiconductor and flat panel display production processes for the manufacture of critical solar power components like thin film panels and solar wafers.[44] Sun Power, a spinoff of Cypress Semiconductor, also uses semiconductor manufacturing equipment to make solar wafers for solar panels in commercial and residential applications. And these recent entrants to the business promise to make waves. With negligible operating costs, the major obstacle to more widespread adoption of solar panels is their high initial cost owing to expensive manufacturing processes. By bringing their standardized and efficient manufacturing processes to bear on solar technology, these companies are likely to help drive down prices and, in the process, make solar energy a more competitive clean alternative energy source.

Harnessing solar energy, once considered an environmentally friendly but expensive and inconvenient power source, is also becoming more efficient with the help of IT. Although solar energy comes from the sun, standalone panels do not always capture the sun's power in the most efficient manner. Newly automated panels, such as those designed by Stirling Energy Systems Inc., use IT to track the sun's rays and respond to clouds and wind. The Stirling system, which can be controlled over the Internet anywhere in the world, even turns its self on and off every morning and night.[45]

Distribution and Consumption Technologies

IT is also revolutionizing the way that we distribute and consume energy. One of the most promising innovations in terms of conserving energy is the so-called "smart grid." In addition, green buildings designed to reduce the overall impact of the built environment are another promising innovation in terms of conserving energy.

The Smart Grid. One reason for high electricity costs is that utilities can accommodate demand increases only up to a certain threshold; beyond that threshold, they must fire up more generators—a process that is energy-intensive, costly for the utility, and when fossil fuels are the energy source, highly polluting. Another reason for high electricity costs is that utilities must build and run enough plants to meet some portion of peak load power demands. If the peak load power demands were reduced, utilities could generate less electricity.

Until recently, power companies have known very little about how the energy is consumed across the grid. Similarly, consumers have had no way of knowing whether running an extra load of laundry on a hot summer afternoon contributes to pushing the system over a given threshold; nor has any pricing incentive for consumers to modify their behavior at such times of peak demand been in place. Thanks to IT, that situation is now changing.

The IT-enabled smart grid uses robust two-way communications, advanced sensors, and distributed computers to improve the efficiency, reliability, and safety of power delivery and use. It also underpins new pricing mechanisms that allow producers and consumers to make better informed decisions about production and consumption according to market incentives, thereby cutting energy consumption and boosting energy efficiency in the process.

The Global e-Sustainability Initiative (GeSI) and the Climate Group forecast that IT can reduce global emissions by 15 percent by 2020, in part, through more energy-efficient transmission and distribution networks. Transmission and distribution losses in India's power sector, for example, could be reduced by as much as 30 percent if more advanced IT and smart-grid technology were used to monitor and manage electricity grids. Yet the energy-saving potential of IT extends far beyond the developing world. Globally, smart-grid technology could reduce $124.6 billion worth of emissions.[46]

The Pacific Northwest National Laboratory (PNNL), as part of the GridWise project, has tested in a demonstration project a system of real-time price monitoring that allows consumers in the state of Washington to control their electricity consumption on the basis of their own preferences. Software is used to maintain a pricing system that updates prices every five minutes to reflect real-time electricity supply and demand. Consumers use a Web interface to set their preferred temperature range; then thermostats and water heaters in individual households communicate wirelessly with the system to respond automatically to these real-time price signals, switching on or off, according to the preformulated household preferences.[47] The PNNL researchers hypothesized that giving consumers better price information about when their energy usage is most expensive, while making the necessary thermostat adjustments an automatic process, would help consumers save both energy and money. Indeed, the study found that, on average, households using the system of real-time price monitoring and automatic responses saved 10 percent on their utility bills. IT-enabled tools such as these can reduce peak load demands on the power grid by up to 15 percent at times of peak demand over an entire year.[48]

A number of companies are offering smart-grid systems. Most rely on wireless or satellite technology to alert participating consumers to curtail energy usage at certain peak times, with the incentive that these on-demand saved megawatts ("negawatts") are sold back to the utility. One such company, Con-

Nissan has found that drivers whose cars are equipped with real-time fuel-efficiency gauges reduce their fuel consumption by 10 percent.

sumer PowerLine, sees energy consumption savings of 15 percent among its customers. Another, SCE, is experimenting with wirelessly enabled refrigerator magnets that alert consumers to times of peak demand.[49] Utilities, too, are getting into the game, exploring the possibility of offering consumers real-time pricing along the lines of the PNNL project.

IT-enabled electronic devices also help make consumers more conscious of the environmental impact and cost of their energy use. One device that consumers can plug into a wall outlet, for example, measures the amount of electricity consumed by a particular appliance. Similar devices monitor electricity usage for an entire home. One such product, the Owl, can display total household energy consumption or compute the financial cost or carbon dioxide emissions based on the energy source and price input by the consumer.

Electronic devices that provide feedback on energy consumption or other factors help individuals make more environmentally friendly decisions in a host of areas, not just electricity consumption. Nissan has found, for example, that drivers whose cars are equipped with real-time fuel-efficiency gauges reduce their fuel consumption by 10 percent. By revealing to people the impact of their driving behavior, such as excessive acceleration, such devices cause many drivers modify their habits to save money. By one estimate, widespread implementation of electricity-demand management tools in the United States would obviate the need for construction of 30 large coal power plants over the next 20 years.[50]

Additional ways in which IT can be used to save energy have been demonstrated in other projects that have incorporated IT into household appliances so the appliances can communicate with the power grid and turn off briefly when the grid is under strain. In a study separate from the one just discussed, PNNL researchers examined clothes dryers equipped to turn their heating elements automatically off until the strain on the power grid is alleviated. The researchers found, in the words of program director Robert Pratt, that the impact of using such clothes dryers was dramatic—"the equivalent of turning power stations on."[51] PNNL estimates that similar controllers could be applied to 20 percent of the nation's energy usage.[52] This tremendous benefit comes at small expense to consumers, whose clothes simply may take a few minutes longer to dry. Findings from Japan confirm the benefits of automated load shifting. One study of a home energy management system that automatically controls home appliances while also letting consumers track their energy consumption and costs found that it reduced home electricity and gas use by between 2 percent and 6 percent.[53]

No less important, IT is allowing utilities to monitor their grids remotely, using optical current sensors that yield critical information for pinpointing outages and other problems when they occur. Working with utilities in Denmark, IBM has found that because these monitoring systems track grid performance and capability, utilities no longer have to overbuild their networks so extensively, instead relying on better information to use existing capacity more efficiently, which can result in capital savings of up to 90 percent.[54]

Green Buildings. In recent years green buildings have gained attention for their efficient use of natural lighting, recycled materials, and other important construction innovations that save energy and promote sustainable living. With buildings accounting for 36 percent of energy consumption and 30 percent of greenhouse gas emissions in the United States,[55] there is room for significant improvement in energy efficiency to reduce energy use and carbon emissions. IT plays an important role in many green designs, particularly their role in improving energy efficiency. The Global e-Sustainability Initiative (GeSI) and the Climate Group predict that using IT to design, manage and automate buildings in North America could reduce the emissions footprint of buildings in our continent by 15 percent.[56]

Many of the most advanced green building designs rely on remote sensors to monitor resource consumption such as IT-equipped thermostats in individual households to reduce energy usage. One builder of green homes called Living Homes equips its homes with remote sensors that monitor energy and water usage, giving homeowners the opportunity to measure their carbon footprint through an Internet application.[57] Using IT to manage more closely the temperature in buildings can yield significant savings. Coordinated control of supermarket freezers and air conditioners, for example, cuts maximum power consumption by 40 percent.[58]

In commercial buildings, in particular, IT is supporting important new energy management tools. IT is especially critical to the design of energy-efficient commercial buildings. Using energy simulation software models, architects can calculate the energy impact of material and design choices over the building's entire lifecycle (through so-called "lifecycle analysis"), and select the best design characteristics that maximize efficiency.[59] Moreover, the use of IT is not limited to optimizing the design process. A program under development in California, called Cal-Arch, allows California building owners to enter their building information and energy consumption, so that they can see a graphical comparison of their energy usage with data from other similarly situated buildings in the same zipcode, thereby gauging their relative energy efficiency.[60] Some IT-driven innovations are even simpler, an example being motion sensors in common areas automatically switch off lights when nobody is around.

In sum, IT is revolutionizing the ways we produce and consume electricity—enabling more efficient, emission-free alternative energy sources, boosting the energy efficiency of the existing distribution network, and other changes that promise to reduce dramatically both our energy consumption and costs.

Reducing Energy Use in the IT Infrastructure Itself

IT has catalyzed a number of important innovations in energy efficiency, but the increasing ubiquity of IT comes with a cost. IT may transform sectors of the U.S. economy, but PCs and the hardware and servers that constitute the backbone of the Internet also use power. As discussed below, however, advances in data center technology and other areas are helping to mitigate the energy impact of the IT infrastructure. For that reason, projections for future IT energy consumption must take into account that much of the continued growth in IT use will be balanced out by improvements in IT energy efficiency.

Before discussing how advances in IT are helping to mitigate the energy impact of the IT infrastructure, however, it should be noted that there has been a considerable amount of misinformation about the

Box 11-1: E-Paper: The Printed Word in the 21st Century

Though the printing press was a revolutionary technology, a new concept called e-paper —or electronic paper—may soon displace the traditional text-on-paper experience. Generally speaking, e-paper is a family of display technologies that manipulate digital ink to display text. Unlike a computer screen, e-paper does not rely on backlights; instead the digital ink is visible just like regular ink on paper. Because power is required only to change pages and not keep the screen lit, battery life for e-paper is typically at least 10 times greater than for a comparably sized laptop.

One application for e-paper is electronic devices known as e-book readers, which can store hundreds of digital books, magazines, and newspapers. Although an e-book can generically mean any digital display that shows a book in electronic form, products now coming to market as e-book readers all tend to rely on some form of e-paper. Network-capable e-paper devices allow users the opportunity to grab text from the Web and to read at their leisure. Kindle, an e-book reader released by Amazon.com, for example, has built-in wireless Internet access through the Sprint network that empowers users to find, buy, and download new books, newspapers, and blog postings without having to use a computer at all. Though e-book readers have been around for a few years, the market has generally not responded with overwhelming demand. Amazon's Kindle has been the lone exception as it sold out quickly upon its release and continues to be hard to find.[61] The three primary limiting factors have been cost, lack of content, and some consumers' preference for paper—the tactile sensation of holding a book and turning its pages.

That being said, the rise of e-paper as a dominant display technology is inevitable. The price of e-book readers will eventually come down. The long-term expectations are that it will be possible to produce e-paper so cheaply that it will be on cereal boxes. As more devices get into the marketplace and demand increases for e-book content, more titles will come online in digital formats. Ultimately, continuing developments in e-paper will allow for things like color, video, and greater interactivity.

energy usage of the IT sector to date. In 1999, in part to critique the energy policy of the Clinton Administration, Huber and Mills published what unfortunately became a widely cited estimate of IT energy consumption in the United States, claiming that Internet-connected computer equipment accounted for 8 percent of the country's overall electricity use and that computer equipment altogether (including non-Internet-connected computers and chips) accounted for 13 percent.[62] These authors anticipated that IT would consume half of the country's electricity by 2009.

Researchers have estimated that for every unit of energy consumed by IT, there is a corresponding savings of 6–14 units of energy.

Several more recent and comprehensive analyses have shown that Huber and Mills' estimates of energy consumption due to IT in the United States, as well as their projections, were vastly overstated. In a thorough analysis, Koomey and a team of scientists at the Lawrence Berkeley National Laboratory found that Huber and Mills' study had overestimated energy consumption due to IT by 88 percent.[63] Using 2000 data, Koomey and his colleagues estimated that IT activities accounted for closer to 3 percent of U.S. electricity consumption—much lower than the 13 percent found by Huber and Mills.[64]

Seven years later, as the transformation to a digital economy has proceeded, IT use in the United States has grown, and the economy relies more than ever on IT. The majority of American adults are now online, and the majority of businesses have intensive IT users.[65] A 2008 estimate by the Energy Information Administration of the U.S. Department of Energy was that IT use accounted for 6 percent of the country's overall electricity use— nowhere close to Huber and Mill's estimate of 13 percent back in 1999 and a far cry from their projection that IT would account for 50 percent of the country's overall electricity use in 2009.[66] The Energy Information Administration projects that U.S. electricity consumption due to IT will continue to grow in the coming years, but at a much slower rate, reaching just 9 percent of U.S. electricity consumption by 2030.[67]

IT may be governed by Moore's Law—continuously growing cheaper and more powerful—but IT's demand for electricity is not governed by this law, at least so far. In fact, as processors become faster, more products and services can be delivered with less energy. Stated differently, advances in IT lead to more output per unit of energy. Whereas cars get around 40 percent more miles to the gallon then they did 30 years ago, IT devices get 2.8 million percent more instructions per watt than in 1978.

Improved Efficiency of Data Centers

To see why projections for future IT energy consumption must take into account that much of the continued growth in IT use will be balanced out by improvements in IT energy efficiency, consider recent efficiency improvements in energy use by data centers, which provide the brains and storage that underpin computer networks and, as a result, are responsible for a growing share of IT energy use. Indeed, one recent analysis calculates server energy demand in 2005 at 1.2 percent of total U.S. electricity consumption—double the amount in 2000. In terms of capacity, this energy use from 2005 is equivalent to the output of five 1,000-megawatt power plants.[68] In fact, data centers have become so power hungry that, according to Cisco, for "every dollar spent on computer hardware, 50 cents are spent on power and cooling."[69]

In response to the growing strain of such energy costs, IT companies are finding ways to lower energy consumption. IBM, for example, is investing $1 billion to improve data center efficiency, with the stated goal of doubling its data center computing capacity over the next couple years without increasing electricity usage.[70] IBM is also promoting mainframe alternatives to the standard data center—its latest z10 mainframe uses 85 percent less energy than a typical collection of servers with a corresponding computing power.[71]

One important innovation for cutting server energy costs is server "virtualization," which allows servers to be more fully utilized by handling multiple applications simultaneously, rather than just one. Because the average server uses only between 5 percent and 15 percent of its capacity,[72] virtualization means that several servers can be combined into one. Fewer servers means lower energy consumption because the electricity usage and cooling demands of a fully utilized server do not differ significantly from one that is running at 15 percent capacity.[73] Cisco estimates that virtualizing servers and storage, combined with optimizing air flow for cooling efficiency and improving server power efficiency could yield operating expenditure savings of 50 percent.[74] According to one estimate, 1.2 million servers have already been virtualized worldwide, resulting in savings of 8.4 billion kilowatt-hours of electricity yearly.[75] Even at the microprocessor level, companies like Intel are working to develop more energy-efficient processors and implement innovative technologies like an open-standard power management protocol to enable control and real-time monitoring of compliant power-conversion products.[76]

By some estimates, between 30 percent and 60 percent of server energy consumption is wasted—and much of the waste is due to inefficient cooling systems.[77] Newer data centers feature more efficiently designed cooling architectures that reduce cooling energy costs from between 15 percent and 40 percent through innovations such as HP's use of three-dimensional modeling called "Thermal Zone Mapping" to cool most efficiently.[78] Indeed, just as with energy-efficiency improvements in other areas, the application of IT forms the basis for achieving energy-efficiency improvements in data centers.

Improved Efficiency of Computers

Data centers are not the only components of the IT infrastructure making significant efficiency improvements. IT and consumer electronics manufacturers are also producing computers and electronics that are more energy efficient.

According to the Climate Savers Computing Initiative, desktop PCs waste approximately half of the energy they consume. Too often computers are left idle when not being used rather than left in power saving mode or turned off altogether. By using power management applications to shut down its computers at night without losing saved information or causing errors, computer manufacturer Dell achieved dramatic results in reducing energy consumption for those computers:[79] The energy consumption of desktop computers at the company dropped from 89 watts per hour to just five watts per hour, and the energy consumption of notebook computers dropped from 15 to 25 watts per hour to merely three watts per hour.[80] Using power management, Dell anticipates reducing its computer-related energy consumption by 40 percent.[81] Dell's newest OptiPlex computers, for example, consume up to 70 percent less energy than previous models through more energy-efficient power settings and better design for more efficient cooling.[82] No less important, computer components are becoming more energy efficient. AMD's "Cool 'n' Quiet" processors, for example, are designed to vary their energy use to match processing needs at a particular time, significantly decreasing overall PC power consumption by as much as 35 watts at a given time.

Aside from the individual efforts of manufacturers, industry members of the Climate Savers Computing Initiative have committed to halving computer energy consumption by 2010 worldwide, saving $5.5 billion in energy costs, and preventing the release of 54 million tons of carbon dioxide yearly.[83] Currently, most people's homes are filled with a multitude of devices that never actually power off; instead, the devices sit in standby when not in use, on average adding more than a hundred dollars annually to the typical energy bill.[84] Although standby mode is important for features consumers want—allowing devices to remember individual settings, for example—some companies, like Nokia, are finding ways to significantly reduce the power draw of their products in standby mode.

Amid the controversy over IT energy consumption that has been brewing since Huber and Mills made their claims in 1999, one fact is clear—namely, that IT infrastructure and hardware will be made more energy efficient. Furthermore, IT is driving and will continue to drive the efficiency improvements that make IT hardware and infrastructure more energy efficient.

Conclusion: IT's Net Impact in the Energy Realm

Clearly, given all the evidence in support of a strong relationship between IT and energy savings, it would be a mistake to consider IT's energy costs in isolation. Instead, net impact is the proper lens through which to view IT's impact on energy consumption and costs.

Although IT's energy costs are often direct, IT's energy benefits can be less direct—a fact that confounds efforts to estimate IT's net impact in the energy realm accurately. Measuring electricity consumption due to IT is fairly straightforward. Measuring IT's benefits is considerably more challenging. As an example, consider the impact of e-commerce—a behavior with a number of indirect energy benefits aside from the immediate benefit of a forgone trip to the local store. Indeed, with enough people shopping for music online, the local music store might disappear altogether, thereby saving the energy that is no longer required to heat and air condition the store, plow its parking lot, or even build the store. In addition, entire supply chain and manufacturing processes are reworked in a more efficient manner, with ripple effects that touch many sectors of the economy. Such benefits of e-commerce enabled by IT are often not immediately apparent, much less straightforward to quantify.

Nonetheless, studies have shown that IT has been a major driver of economic growth, a fact which complicates analysis somewhat, because more economic activity will often mean more pollution, even if that additional activity is less energy-intensive than it might otherwise be. An examination of recent history suggests that IT has had an appreciable positive effect on energy intensity (energy used per unit of gross domestic product). From 1996 through 1999, the United States experienced an unprecedented 3.2 percent annual reduction in energy intensity (energy used per unit of gross domestic product)—four times the rate of the previous 10 years.[85]

Although several factors may account for this reduction in energy intensity, including the shift in the U.S. economy toward less energy-intensive sectors, the incorporation of IT into business practices appears to be a key source of the improvement.[86] In a recent statistical analysis, Laitner and Ehrhardt-Martinez found, on balance, that for every unit of energy consumed by IT, there is a corresponding savings of 6–14 units of energy.[87] Thus, although IT itself requires energy, albeit less and less, using IT yields a large savings of energy by making activities more energy efficient, with the end result that IT is responsible for significant net energy savings.

In the future, it is reasonable to expect that IT will continue to drive energy-efficiency improvements. A report by McKinsey Global Institute estimates that cost-effective investments in existing technologies and energy productivity techniques could improve energy production by 25 percent over the next 20 years.[88] That report considers a host of proven steps that could be taken, all with a minimum 10 percent rate of return, from more efficient lighting to implementation of more advanced combined cycle power plant technologies. Not all of these benefits can be chalked up to IT, but IT clearly has contributed to many of them, including the development of more efficient home appliances.

Similarly, the Lawrence Berkeley National Laboratory estimates that IT could reduce the growth in projected carbon emissions by one-third over a 10-year period.[89] The lower projections result from the anticipated continued diffusion of IT in a range of areas, including e-commerce, reduced paper and cement consumption, advanced business and supply chain management practices, telecommuting, alternative energy, growth in less energy-intensive IT sectors relative to more energy-intensive sectors, and IT-driven efficiency improvements in a wide range of equipment.

A similar study in Japan estimates that widespread deployment of IT could curtail carbon emissions by over 40 percent by the year 2050.[90] This estimate relies on projected benefits from ubiquitous home energy management systems, vehicle driving support systems, intelligent transportation systems, and supply chain management and also assumes widespread (68 percent) full-time teleworking participation.[91] Though a 40 percent reduction in carbon dioxide emissions is an ambitious target, the study in Japan offers a useful picture of what is possible in a digital society of the future.

Yuji Inoue, CEO of the Telecommunication Technology Committee of Japan, has estimated that Japan could reach 90 percent of its Kyoto targets for reducing carbon emissions through the application of IT alone.[92] Fuhr and Pociask have estimated that broadband networks, if widely adopted, could result in a net reduction over 10 years of 1 billion tons of greenhouse gas emissions. They calculate that this amounts to the equivalent energy savings of 11 percent of oil imports.[93]

Though there are relatively few authoritative studies on IT's net energy impact, the available evidence—both statistical and anecdotal—strongly suggests that IT is driving energy-efficiency improvements. It is reasonable to expect the trend toward IT-driven improvements in energy efficiency to continue, in no small part because many of the most promising IT-driven innovations in energy savings are still in the early stages of implementation. The net energy impact of IT in the future will heavily depend on how quickly and fully society adopts telecommuting, e-commerce, and other energy-saving practices, and whether we implement policies to spur their adoption. Both our energy future and the future of a warming planet hang in the balance.

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12. Transportation

As anyone who has driven a late-model automobile knows, information technology (IT) has made major inroads into the personal vehicle. Most late-model cars have at least an auxiliary input to the sound system for iPods and other music players, and some offer full integration of portable media players to allow selection of music by title, artists, genre, or other criteria. They have antilock braking systems that electronically monitor the speed of the wheels and regulate the hydraulic pressure to improve stopping power and control on dry, wet and icy pavements. And cars increasingly have navigational systems that rely on satellite technology to help drivers find where they want to go.

These changes in personal vehicles began to appear in the latter part of the 20th century following improvements in sensor, computational, and communication technologies. Previously, interactions between automotive vehicles, occupants, and their environments consisted of a few simple elements. A vehicle's tires interacted physically with the roadway; and systems in the vehicle such as power braking, power steering, and cruise control assisted the driver in operating the vehicle safely and comfortably. The driver (and passengers) generally sensed the environment by relying on visual observation (through the windshield, side windows, and rear view mirrors); tactile sensation (the feel of the steering wheel, pedals, and other control devices, and the movement of the vehicle itself. Most vehicles were equipped with a one-way radio (AM or FM), and some had two-way mobile communication devices (e.g., CB radio, police radio). The driver paid attention to pavement markings, traffic signals, signs, and billboards. For people outside the vehicle, information about a vehicle and its occupants came primarily from observing such things as driving speed or patterns, the vehicle's license number, inspection certificates, etc.

Following improvements in sensor, computational, and communication technologies in the latter part of the 20th century, in-vehicle systems such as antilock braking systems and adaptive cruise control began to proliferate and improve. In addition, in-car concierge systems like General Motors' OnStar that rely on cellular networks and in-car navigational devices that rely on satellite systems began to appear. Personal vehicle owners are not the only ones in the transportation sector who have benefited from improvements in sensor, computational, and communication technologies. Highway owners are using automatic, electronic toll collection systems such as E-ZPass in the eastern United States and FasTrak in California to improve the efficiency of toll collection, reduce fuel emissions, and help manage congestion. Public transit providers are incorporating IT into their control systems and using it to provide better information to transit patrons. And on the horizon are "intelligent transportation systems" with ubiquitous connectivity that can provide real-time warning and safety information to vehicles on the road to prevent fatalities and injuries, improve public transit, reduce traffic congestion, improve the allocation of resources to the transportation infrastructure, and mitigate transportation's negative impacts on the environment.[1]

As described below, the combination of sensor, computational, and communication technologies—or telematics—in the transportation sector has opened up a whole range of new possibilities for improving access to transportation-related information; enhancing the safety of transportation; and improving transportation system monitoring and management.

Systems are being deployed that would indicate to drivers where vacant parking spaces are located and would even allow drivers to reserve parking spaces in advance.

Improving Access to Transportation-Related Information

One of the big benefits of IT is improving access to transportation-related information. As discussed below, applications of telematics collectively promise to make our transportation systems come alive with information.

Directions for Getting Places

Thanks to the Internet, a vast amount of information is available to anyone contemplating a trip of any length from a walk to the corner store (is it open at this hour?), to a drive or bus trip across town (how is the traffic?) or across the country (how far is it and what is the shortest, or most scenic, or least congested route?). Online booking of travel for air, train, or rental car is now par for the course. Checking the status of a flight to see if it is on time or has been canceled is easily accomplished by mobile phone or Web browser.

Both Google and Microsoft now have systems announced or already available that will provide traffic information in real time. Google Maps provides a "traffic" button on its maps in metropolitan areas that shows red-yellow-green indicators for traffic speeds. And Google recently introduced a feature that reports "normal" traffic levels by the time of day and day of the week. Microsoft has announced a new software feature called Clearflow that uses artificial intelligence to provide navigation advice that takes into account expected traffic conditions on a roadway-by-roadway basis.[2]

Finally, cars in the United States increasingly have global positioning system (GPS) navigational devices—either a factory installed GPS device, a GPS device installed after the vehicle's purchase, or a mobile GPS device such as those available from Garmin or on mobile phones. Factory-installed GPS devices are currently available on 69 percent of all vehicle models sold in the United States. In 2007, 1.8 million navigation systems were sold, bringing the total to 7 million units with GPS-based navigation on the road.[3]

Information About Ridesharing, Public Transportation, and Car Sharing

IT is making it easier for drivers to connect with potential passengers traveling between the same origins and destinations, improving public transportation, and making it possible for car sharing companies to give urban dwellers access to a car at a moment's notice without actually owning one.

Casual carpooling systems are already in place in a few cities around the United States. Passengers stand in shopping center parking lots near high-occupancy vehicle (HOV) entrances, and drivers cruise by to find a passenger going to approximately the same destination. In the evening, the reverse process occurs. Picking up an extra passenger provides drivers with access to an HOV lane or someone to share the cost of a toll. A more technologically advanced system to facilitate "on the fly" ridesharing, could provide added safety and efficiency, and increase market share.

On the public transit front, a major barrier to more widespread adoption of public transportation is that commuters—especially in America's sprawling suburbs—personally find public transit to be less efficient than driving a car. Personalized public transportation is designed to directly address these problems by tying together several modes of public transportation through IT, minimizing wait times in the process. A personalized public transportation system can deploy circulating on-call minibuses, for example, to pick up individual passengers and bring them to a waiting train or bus that might travel between suburbs or into a central city. A Finnish software company called MobiSoft has developed software for this sort of personalized public transportation network that works over existing mobile phone networks.[4]

A number of public transportation systems are also using telematics to improve existing services. One of the leaders is Paris. Bus stops in Paris have a digital display that shows when the next bus is expected to arrive for each line serving the stop. During the city's transit strike in fall of 2007, the signs were updated to announce the lack of service. The subway system in Washington, D.C., has a similar system that shows estimated train arrival times for every station in the system. The bus system in Washington has also experimented with a "Next Bus" system that shows information about arrival times for buses based on real-time tracking of bus locations available via Web-enabled mobile devices.[5]

Giving urban dwellers cheap access to cars makes people more likely to give up owning a car that they seldom use, resulting in fewer cars, more efficient utilization of resources, and lower carbon emissions. Car-sharing companies like Zipcar allow consumers to use the Internet to easily rent locally located cars at a moment's notice. Car sharing would be impossible without the Internet to locate and coordinate the substitutes for personally owned cars and without IT-enabled car locks that let only the user drive the car.

Finally, some companies are relying on IT to transform their employees' commutes to and from work. Microsoft, for example, now offers employees at its headquarters in Redmond, Washington, the opportunity to travel to work aboard one of its new fleet of Wi-Fi-enabled buses. Not only are the buses a more environmentally friendly means of transportation, but their computer jacks and Wi-Fi access also allow Microsoft's employees to become more productive by working during their commute.[6]

Parking Information

For people who have arrived at their destinations, telematics is increasingly helping with information about parking. Parking is one of the more complicated phenomena in the transportation sector, giving rise to questions such as how much parking to provide, how to price it, how to enforce it, where to locate it, and how to design it so it is visually attractive.

Telematics has the potential to make parking a little easier to manage both from a user and a provider standpoint. At Baltimore Washington International Airport, for example, the recently opened parking deck has a system that shows how many spaces are available on each parking level. When drivers reach a particular parking level, red and green lights above each space that are visible from the end of the aisle allow them to quickly determine whether an aisle has any vacant spaces.

Finding a parking space on the street may also get easier with telematics. Systems are being deployed that would indicate to drivers where vacant spaces are located and would even allow drivers to reserve spaces in advance. San Francisco, where in 2007 a teenager was stabbed over a parking spot argument, is installing wireless sensors in 6,000 parking spots. Drivers will automatically be able to know where an empty spot is by either downloading the information onto a cell phone or GPS device or looking at street signs that are hooked up to the system.[7] Pooled parking markets have also been proposed. Parking space owners, including homeowners or retail stores, could register their parking places in an auction or reservation system, thereby allowing enrolled users to bid for or reserve a space, which could be charged to a linked credit card.

Given that 30 percent of urban traffic in some cities consists of drivers cruising for curb parking, smart parking systems made possible by telematics have the potential to provide benefits not only in terms of reducing frustration but also of reducing congestion, reducing fuel consumption, and improving air quality. One survey found 45 percent of the cars driving in Park Slope in Brooklyn, New York, were searching for a parking spot on the street.[8] Another survey found that in one small Los Angeles business district, drivers looking for parking spots drove the equivalent of 38 trips around the world throughout the course of a year.[9]

Telematics is even helping with the pesky problem of parallel parking the car in the city. On its LS model, Lexus is currently offering an advanced parking guidance system that parallel parks the car automatically. The driver positions the vehicle slightly forward of the open space, and the vehicle does the rest (the driver controls the speed using the brake pedal, but the system handles the steering). (It is not clear whether this system will be allowed for use during driving tests at the local department of motor vehicles.)

Another area where telematics is coming into play is parking enforcement. The District of Columbia and other jurisdictions are on the verge of deploying high-tech parking enforcement systems that automatically read license plates and vehicle locations while the parking enforcement vehicle moves along the street. On the next pass of the parking enforcement vehicle, the high-tech system quickly identifies vehicles that have overstayed a space that allows parking for only a limited time, such as one or two hours—even if the vehicles' owners have fed the meter. Such enforcement would free up curb spaces, potentially reducing the amount of time others cars spend cruising around looking for a parking space. (It might also just put another car back on the street cruising for an open space on the next block.)

Information Tailored to an Individual's Location

Telematics makes possible applications that sift and present information based on an individual's location—sometimes called location-based services. On the Internet, for example, individuals can go to Google Maps, MapQuest, or other online mapping systems and type in a specific location; the mapping application will then find and identify services (e.g., gas stations, restaurants, hotels) nearby. Thus, such mapping systems can even direct individuals to the nearby station with the cheapest gas or a station that sells diesel fuel.

In addition, concierge services available by subscription through General Motors' OnStar, Mercedes' Tele-Aid, and similar services have used a vehicle's location read from the vehicle's onboard GPS transponder, in combination with databases used by a concierge, to find restaurants, hotels, Wal-

Marts, and other establishments near the vehicle, as well as to help with traffic navigation. Such systems, which have been available for a decade or more, are increasingly fully automated. Possible extensions of such systems may give retailers opportunities to offer promotions (e.g., coupons, discounts, or other incentives) to vehicle occupants that are based on the vehicle's location in real time.

Improving Transportation Safety

One of the biggest potential benefits of telematics is significantly improving transportation safety. In 2006, almost 43,000 people in the United States died in vehicle crashes. Telematics has the potential to reduce that number by providing a rich stream of information to and from automotive vehicles and even preventing accidents through collision warning and avoidance systems, speed advisories, and even speed control systems.

In-Vehicle Safety Systems

A host of in-vehicle safety systems enabled by telematics are already available. Adaptive cruise control, which maintains a minimum distance between a vehicle ahead, reduces the risk of rear-end accidents. Side-looking and rear-looking sensors warn drivers of objects behind them when backing up or in adjacent lanes if the driver begins to change lanes and risks a collision. Sensors can warn drivers when tire pressures are below specification, or even when tires are wearing out.

One challenge is making in-vehicle safety systems affordable. At General Motors, current onboard safety systems use up to eight separate sensors (cameras and radars) to provide 360-degree visibility around the vehicle. The cost of these systems is on the order of thousands of dollars per vehicle because of the expense of the sensors themselves, their integration with other onboard systems, and servicing their warranties. The high cost limits the use of such security systems to luxury or premium vehicles.

With dedicated short-range communication (DSRC) tags that offer the potential of a single-sensor in-vehicle safety device, the price barriers may come down. Thus, it may be possible to offer much more advanced safety features on a broader price range of vehicles, or even to make them standard equipment on all vehicles. If automakers installed DSRC tags on all vehicles, a world of opportunities opens up, building on a virtuous cycle of a broadening installed base of DSRC-equipped vehicles and a broadening range of services and applications that could be provided economically.

On the transportation safety front, the Holy Grail is collision avoidance via what are known in the trade as "cooperative intersection collision avoidance systems" (CICAS). For CICAS to work, most or all vehicles on the road would have to be equipped with DSRC tags, and the necessary roadside equipment would have to be widely deployed. In that case, two DSRC-equipped vehicles approaching an intersection would be in continuous communication with roadside devices that would recognize when a collision was imminent and warn the drivers of an impending collision or communicate with the vehicles to brake or take appropriate evasive action.

Telematics has the potential to make possible a rich stream of information to and from automotive vehicles and prevent accidents via collision warning and avoidance systems, speed advisories, or even speed control systems. But the vehicle fleet takes more than a decade to turn over, and installing and maintaining hundreds of thousands of roadside devices poses challenges for state departments of transportation that are strapped for funds. For that reason, the goal of the Vehicle Infrastructure Integration initiative that has been undertaken by the Research and Innovation Technology Administration at the U.S. Department of Transportation is to

Telematics can create a rich stream of information to and from vehicles and prevent accidents via collision warning and avoidance systems, speed advisories and speed control systems.

work toward deployment of the advanced vehicle-vehicle and vehicle-infrastructure communications that are necessary to avoid collisions.[10]

Better Traveler Information and In-Vehicle Signage

A number of applications for DSRC would be available on the first day factory-installed DSRC-equipped automotive vehicles hit the street. Several of these Day 1 applications are intriguing. One would be improved traveler information. Drivers could receive information about estimated travel times, like the currently available navigation systems, as well as alerts about construction, road closures, detours or traffic incidents on the route ahead. Another Day 1 application would be in-vehicle signage that would alert the vehicle's driver to speed limits, school zones, stop signs, etc., as the trip progressed. Ideally, traffic control zones that changed by time-of-day and day-of-week would be announced only when active.

An estimated 5 percent to 10 percent of the congestion on major roadways in America today—amounting to 295 million vehicle hours—is due to bad signal timing.

In-vehicle signage could also provide information about roadside services at highway exits, replacing or supplementing the familiar "gas-food-lodging" signs currently in use.

Improved Traffic Signal Timing

Another goal of the transportation world that DSRC would help with is improving the timing of traffic signal timing. How many times have you waited seemingly forever at a red light while no cross traffic went through the intersection? Shouldn't the system "know" there was nobody using the intersection?

Better timing of traffic signals would allow the owners and operators of highways to improve traffic flow and reduce congestion. The problem today is that most of the signal timing in the United States is based on seriously outdated traffic information. Developing a traffic signal timing plans requires lots of data. The optimal signal timing plan depends on the relative volume of traffic going through the intersection. If there is a heavy thoroughfare intersecting with a lightly used cross street, most of the green time should be allocated to the thoroughfare. If there are two thoroughfares with roughly equal traffic, the green time should be more evenly divided. More complicated intersections with dedicated left turn lanes or multiple streets intersecting require more elaborate signaling plans. Traffic flows can also be considerably improved if adjacent intersections along a thoroughfare or even across a whole network are coordinated. And of course, traffic patterns vary by time-of-day, day-of-week and around holidays, as well as with the share of automobiles, buses and trucks that make up the traffic stream. Signal timing plans should reflect all of these factors.

Therein lies the challenge: collecting all the data needed to inform signal timing plans is time-consuming and extremely expensive. The old fashioned pneumatic tube counter, which lies across a traffic lane, has been supplemented by more advanced sensors that automatically count and classify the types of vehicles using a lane. But even so, the Achilles heel of traffic engineers for decades has been bad data. The vast majority of the 272,000 signalized intersections in the United States use outdated timing plans based on data that was collected years or decades ago, or perhaps just based on typical plans looked up in a handbook. The signals at one key intersection in Washington, D.C., still allocate green time for traffic on a road that has been closed since September 11, 2001. An estimated 5 percent to 10 percent of the congestion on major roadways in America today—amounting to 295 million vehicle hours—is due to bad signal timing.[11]

Telematics has the potential to make data collection much easier. DSRC-equipped vehicles could provide traffic engineers with an affordable and continuous data source for updating and maintaining signal timing plans. That way, traffic signals would become "intelligent." And having intelligent traffic signals would offer several benefits, not only reduced delays for people on the road but also reduced fuel consumption and tailpipe emissions.

Roadway Weather Information

Telematics has the potential to provide greatly improved information about roadway weather, such as road surface temperatures and visibility. With an "intelligent transportation system," vehicles operating on a roadway could act as weather "probes" sending information to a control center, which could then compile the data to provide much greater detail about real-time conditions. Such information could be provided to individual motorists, along with information about whether a particular road had been treated, and how recently—e.g., the system could warn a driver of icy road surfaces ahead, using a visual and/or an audio alert. Such information could also be used to deploy snow and ice treatment operations more efficiently and effectively.

Europeans are experimenting with a system called "intelligent speed adaptation," which allows a system external to a vehicle to provide a warning when the vehicle exceeded recommended speeds or actually limit the vehicle's speed. The limitations on vehicles' speeds imposed by the system could be based on real-time weather or road conditions, or simply on the posted speed limit for a roadway.

Improving Transportation System Monitoring and Management

Currently, most roads in the United States are not managed in any active way; they are just built and then many seem to be forgotten about. But IT is beginning to change that by bringing intelligence about the transportation infrastructure to transportation system managers. IT also has the potential to improve the allocation of resources to the transportation infrastructure.

Monitoring Transportation Infrastructure

The catastrophic collapse in Minnesota of the eight-lane Interstate 35W bridge across the Mississippi River in 2007 clearly illustrates transportation managers' need for real-time information on the state of bridges, highways, and other transportation infrastructure. That incident led Lee and Sternberg to propose the deployment by the United States of a national bridge monitoring and reporting system that would use electronic sensors embedded in bridges to monitor and report on their structures. Electronic systems are more accurate than manual testing and would alert bridge owners in the event of extreme events, such as excessive loads or structural failures.[12]

Transportation departments in more than 20 states already deploy wireless sensors on bridges that can detect cracks and stresses. These sensors monitor vibration, temperature, and corrosion, as well as sounds such as creaks and popping cables that reveal structural problems before they can cause a catastrophe.[13]

A country at the forefront of remote bridge monitoring is South Korea. The Korean Bridge Management System is a network of wireless sensors that connect to a centralized database that analyzes and stores 230 variables per bridge including carry capacity and environmental variables such as vibrations, temperature, and humidity to help ensure the safety of these structures.[14]

IT-enabled systems for monitoring pavements have been proposed as a method for improving road safety. Sensors embedded in the pavement can provide real-time, continuous data on the condition of pavement surfaces, such as temperature or presence of ice. Electrical power and water distribution companies have long used computer-monitored "supervisory control and data acquisition" (SCADA) systems to acquire data on the system status and to control devices on the system from a control center. The deployment of similar SCADA systems to monitor and manage highways and transit systems could lead to significant improvements in efficiency and effective control.

Improving the Allocation of Transportation Resources

IT boosts allocative efficiency—the production of the right goods for the right people at the right price—by enabling the creation of markets and market signals in areas where market signals have not generally existed. In the transportation sector, for example, IT enables roadway space to be allocated on the basis of demand and price. Economists have long recognized that road pricing (charging by distance traveled, place traveled and/or time of day), is the most efficient way to allocate scarce transportation resources. But until recently, it was too expensive and cumbersome to institute road-pricing schemes. Now the emergence of inexpensive vehicle transponders and other technologies is allowing regions to institute road pricing. An electronic road pricing program in Singapore, for example, reduced morning traffic volume by 45 percent as many travelers opted to carpool, take transit or telecommute; and the program almost doubled average speeds in the restricted area surrounding the central business district.[15]

In the United States, IT is allowing regions to make more efficient use of the more than 1,600 miles of HOV lanes operating in 31 metropolitan areas. Most of the time, HOV lanes are underutilized. IT-based transponders allow regions to let cars willing to pay a toll use these lanes, with the result that throughput on the roads goes up and additional investments in new, expensive roads are not immediately required.[16] Electronic toll payment is already available with the current generation of electronic tags like E-ZPass and FasTrak. Airports in New York are even allowing payment for parking with E-ZPass. By allowing vehicles to pass through toll plazas more quickly, these systems cut pollution and fuel consumption. Similarly, new technology can weigh trucks on the fly, making the stopping and idling that used to accompany truck weigh stations no longer necessary. The fuel and emissions savings from reduced congestion can be enormous, especially if traffic congestion increases fuel consumption by 80 percent, as has been estimated.[17]

Stockholm's automatic tolling system is a pioneering example of how IT can help to alleviate congestion and reduce pollution by discouraging automobile travel at peak travel times. Under the system, tolls for the roads vary depending on the time of day, type of car (hybrids pay less), and route traveled, with the highest fees applied during peak rush hour when pollution is worst to encourage commuters to seek out alternative transportation. Underpinning the system is an IBM network that includes access points that correspond with smart tags in vehicles to deduct tolls automatically from drivers' accounts. Drivers without smart tags can pay tolls over the Internet, and their usage of the roads is tracked by a camera system that captures and identifies license plate numbers.[18] Such sophisticated tolling—both tailored and "on the fly" to avoid impeding traffic flow—would not be possible without smart systems that rely on information technology.

Stockholm's congestion pricing scheme has yielded immediate results, reducing traffic by 25 percent in the first month of implementation as legions of commuters opted for public transportation.[19] After a seven-month trial period, the system was so popular that voters approved its permanent implementation. And Stockholm is not the only city experimenting with IT-based traffic management. London has successfully implemented a similar system, and plans to extend its variable pricing to reflect the carbon emissions of particular vehicles, charging higher fees to less fuel-efficient cars.[20] Meanwhile, Singapore is taking the idea even further, working to develop a system that predicts traffic flow based on a network of sensors and cameras—including sensors in taxi cabs to monitor traffic flow in real time—in order to improve traffic management.[21]

Through telematics, big benefits for consumers and for transportation system operators seem to be within reach.

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13. Public Safety

In addition to improving the quality of life for millions of people, information technology (IT) in many instances is being used as a tool to actually save lives. IT is used to improve the safety of individuals every day, although many do not realize its importance. Fifteen years ago, efforts to stop crime and terrorism relied on traditional mechanisms: strict physical security at vulnerable facilities, intelligence gathering by government agents, vigilance on the part of all citizens, and a sense of community in which all citizens played a role in protecting each other. These techniques have not been replaced, but nations today have IT as an additional powerful, new tool to ensure public safety.

Much of public safety relies on getting the right information to the right people. Governments use IT to secure their borders against external threats, aid law enforcement in fighting crime, and help communities prepare for, and recover from, disasters. Law enforcement agencies use IT to communicate and share information, monitor and detect crime, and respond to disasters. Finally, IT is at the forefront of the science used by researchers to better understand the complex weather systems that constantly threaten our societies. The IT revolution has given governments the tools, infrastructure, and capabilities to make public safety easier, less expensive, and more effective.

Keeping the Nation Safe

To effectively secure a nation, a government requires accurate information about the individuals and materials entering and leaving the country. As discussed below, IT plays a critical role in securing national borders and managing the flow of people and goods through a country's points of entry. Furthermore, as nations face new threats of terrorism, governments have turned to IT for an array of new tools to detect threats to national security and thwart possible attacks.

Securing National Borders

To prevent unauthorized entry and to facilitate legitimate trade and travel, the United States and other countries increasingly use IT-based tools—including biometric information such as fingerprints, DNA, iris patterns, or facial characteristics and digital photographs—to accurately identify and authenticate both individuals and shipments.

The United States has an IT-enabled system for immigration managed by the U.S. Department of Homeland Security. This program—called US-VISIT—requires all non-U.S. citizens between the ages of 14 and 79 to supply fingerprints and digital photographs when they enter the country or apply for a U.S. visa. These are intended to help in the accurate identification of foreign travelers and in preventing the use of forged or stolen visas. They are shared with the Federal Bureau of Investigations (FBI) and cross-matched against the Department of Homeland Security's watchlist of criminals, immigration violators, and known or suspected terrorists.[1] By the end of 2008, the Department of Homeland Security expects to implement US-VISIT in all U.S. ports of entry.

In the United Kingdom, an e-Borders program similarly collects and analyzes information about individuals entering or leaving the United Kingdom. Under the e-Borders program, airlines, ferries, and rail companies collect electronic information regarding passengers traveling to the United Kingdom and transmit this information to the government to analyze. Data collected in the program are used to coordinate efforts across the government including border patrol, law enforcement, and intelligence agencies.[2] Similar initiatives are being developed elsewhere. In Asia, for example, the Asia-Pacific Economic Cooperation is coordinating an effort to develop an interoperable electronic movement records system. By collecting advanced passenger information for air travel, countries can prescreen passengers before they arrive at the border and have more time to review any possible threats.[3]

The United Kingdom plans to add a biometric component to its e-Borders program to automatically identify individuals at official ports of entry.[4] In fact, the United Kingdom has already implemented a system—the Iris Recognition Immigration System (IRIS)—that allows registered travelers to use biometric identification to quickly enter the country through automated barriers at certain airports, including all five terminals at London's Heathrow Airport. Under IRIS, a camera identifies a traveler from his or her iris pattern; the system then verifies

In the UK, the Iris Recognition Immigration System (IRIS) allows registered travelers to use biometric identification to quickly enter the country through automated barriers at certain airports.

that the passenger has met the entry requirements without requiring any additional passport or visa information.[5]

In recent years, countries in the European Union and the United States have introduced electronic passports—"e-passports"—with biometric information. An e-passport typically contains a radio-frequency identification (RFID) chip, which stores not only the standard passport data but additional digital biometric information such as a photograph, iris pattern, or fingerprint. E-passports help governments better authenticate passport holders and reduce the risk of tampering to these travel documents. The information stored electronically in the e-passport is digitally signed and encrypted to prevent counterfeiting and manipulation. To promote interoperability, most countries use a standard biometric file format defined by the International Civil Aviation Organization. The exact implementation of e-passports varies by country. The only biometric data stored on U.K. e-passports, for example, is a photograph[6]; German e-passports, in addition to including photographs and personal information, contain two fingerprints.[7]

Using biometric-enhanced e-passports, government officials can more quickly and accurately process travelers through customs and immigrations. The Australian government has established SmartGate kiosks at its international airports to allow travelers with Australian or New Zealand e-passport holders to self-process through the passport control area.[8] The SmartGate system uses data in the e-passport and facial recognition technology to perform the customs and immigration checks that are usually conducted by a Customs Officer. SmartGate will be gradually opened to other nationalities that have International Civil Aviation Organization-compliant e-passports.

The demands of physically protecting a nation's border are daunting. In the United States alone, government officials are charged with operating 324 official ports of entry and protecting 5,000 miles of border with Canada, 1,900 miles of border with Mexico, and 95,000 miles of shoreline.[9] IT—particularly in the form of surveillance cameras and sensing devices—plays a key role in providing government officials with the tools they need to secure the borders.

A critical component of the U.S. Department of Homeland Security's comprehensive, multiyear plan to secure U.S. borders and reduce illegal migration launched in 2005—the Secure Border Initiative—is SBInet. SBInet is a comprehensive program whose goal is to field an appropriate mix of state-of-the-art technology and infrastructure and integrate them into a single border security suite for the Department of Homeland Security.[10] The plan is to integrate multiple state-of-the-art systems and sensors, including more expanded use of unmanned aerial vehicles (UAVs), remote-video surveillance camera systems, and sensors.[11] Agents on the ground can use real-time information relayed from radar, surveillance towers, and ground sensors to their satellite phones and handheld devices to track targets on a map and locate unauthorized entries.[12]

Advances in IT have led to the development of UAVs with better remote control, enhanced sensors, and more autonomy. The U.S. Department of Homeland Security uses UAVs to scan remote areas, augmenting ground patrols that lack the manpower and time to reach these areas. UAVs provide precise imagery in real time that enables agents to quickly determine border breaches. One type of UAV—the Predator B—was deployed by the Department of Homeland Security in Operation Safeguard, an experimental law enforcement program conducting missions along the U.S.-Mexican border.[13] The Predator B can fly for 30 hours without refueling, so it can provide sustained coverage over exposed geographic areas.[14] UAVs are also less expensive than manned aircraft. A Predator UAV, for example, costs $4.2 million, whereas a P-3 manned aircraft used for by the U.S. Customs Service for border patrol costs $36 million.[15]

In every nation, customs and immigration officials work to prevent the entry of contraband such as hazardous materials, illegal drugs, and weapons from entering the country. The majority of heavy goods—such as cars, trucks, and appliances—enter the United States in maritime cargo containers. U.S. Customs officials do not have the capacity to inspect every shipment. For that reason, the U.S. Department of Homeland Security has launched its Container Security Initiative. The purpose of this initiative to ensure that cargo containers entering the United States are inspected as early in the supply chain as possible. With intelligence and information collected in advance (e.g., the cargo manifest), the Department of Homeland Security uses software to automatically identify high-risk containers to target for inspection. Then, rather than waiting for goods to arrive at domestic ports, inspectors use large-scale X-ray and radiation detection devices to examine containers at the port of departure. The Container Security Initiative has been implemented in 58 ports, covering nearly 90 percent of all container traffic coming to the United States.[16] In addition, the Transportation Security Administration of the Department of Homeland Security has created a biometric transportation worker's identification credential, which all individuals must show to enter secure areas at certain ports and on certain vessels.[17]

Screening Cargo and Passengers

Bomb-sniffing dogs are one of the most effective tools for detecting explosives; however, it is not practical to have bomb-sniffing dogs check every person and shipment that enters the country. For that reason, researchers have sought to design electronic devices that will replicate canines' keen abilities.

One such device, funded by the U.S. Defense Advanced Research Projects Agency (DARPA) uses tiny chemically coated sensors called microcantilevers (very small narrow boards) to detect molecules by gauging how they cause surface sensors to bend or vibrate.[18] By analyzing how the sensors behave, scientists can tell how many and what kind of molecules are present. To create a handheld chemical detection system, the company developing the system placed an array of these chemically coated microcantilevers into a device the size of a mobile phone. During tests, the device successfully identified not only explosives but also toxic industrial chemicals and biological threats. DARPA plans to use such devices as mounted sensors inside shipping containers. Transportation Security Administration screeners also could use the devices to screen airline passengers for explosives.[19]

Security officials in the United States and elsewhere have also worked to improve the technology for passenger screening. Some experts have advocated the use of whole-body imaging to detect explosives, plastic weapons, and drugs on passengers that traditional scanners miss. Critics of the current system of screening airline passengers by having them walk through metal detectors and then screening them by handheld scanners, including the U.S. Government Accountability Office, point out that this approach is ineffective against many risks.[20] Whole-body imaging uses backscatter X-rays or millimeter wave technology to give screeners a detailed view of the passenger's body by constructing images from the X-ray photons or radiation reflected by the body. Already such systems have been used in many airports including JFK International Airport in New York, Los Angeles International Airport, and London's Heathrow Airport.

Whole-body imaging essentially provides a detailed view of the traveler's body, and some people object to this as being too invasive. It is nonetheless one of the most accurate way to detect passengers carrying weapons or explosive devices.[21] To address privacy concerns, vendors have introduced a number of controls including a privacy filter that digitally alters the image displayed to the screener to show only the outline of an individual's body. Whole-body imaging devices can also be configured to detect weapons and explosives from a distance of 15 feet to 30 feet, enabling security officials to scan airport lobbies and entrances to subway and rail stations.[22] Eventually imaging systems that use backscatter X-rays or millimeter wave technology may replace metal detectors used for personnel security in other public venues. These imaging technologies can also be used to scan vehicles, cargo, baggage, and mail.

Although security officials focus much of their effort on preventing criminals and weapons from entering the country, they also work to prevent and detect attacks from threats already within the country. Researchers at Purdue University are developing a system to detect and track radiation from nuclear threats—such as a dirty bomb—using a network of mobile phones.[23] Tiny radiation detectors are already commercially available, and although the radiation detection system these researchers are developing would require additional circuitry, the sensors would be small enough that manufacturers could place them in mobile phones, laptops, and personal digital assistants (PDAs) without adding extra bulk. Some mobile phones contain global positioning system (GPS) technology, which would enhance the detection of radiation by precisely locating its source.

Software built into the radiation detection system's network would then evaluate the levels of radiation and its threat. In a recent test, mobile phones with the built-in sensors detected radiation from 15 feet away.[24] The radiation detection system can use data from many different mobile phones to pinpoint the source of the radiation. The main challenge would be achieving a high enough rate of adoption of devices with the sensors, either voluntarily or by mandate, for the system to provide an effective layer of protection.

Analyzing Large Sets of Data for National Intelligence Information

Investigators have found that intelligence officials often had evidence of an impending attack prior to a terrorist strike but failed to connect the dots in time to prevent the attack.[25] IT provides government officials valuable tools to efficiently analyze large sets of data and derive useful intelligence—intelligence that may allow officials to detect terrorist and criminal activity in time to do something about it.

One way that IT helps government analysts connect the dots is by making it possible to share information quickly. In 2007, the Central Intelligence Agency in the United States introduced Intellipedia. Much like the user-built, Web-based encyclopedia Wikipedia—built with Wiki software designed to enable anyone who accesses it to contribute or modify content—Intellipedia allows analysts from different departments to post, read, and edit information on security intelligence. Intellipedia also has other Web 2.0 features such as photo and video sharing, content tagging, blogs and RSS feeds. Each entry in Intellipedia is organized by topic, not by corporate structure, and this organization allows the contributors to act like "a community of analysts rather than a community of agencies."[26] Such a medium helps spread ideas from "base camps of knowledge" across traditionally departmentally demarcated lines of jurisdiction.[27]

The CIA has introduced Intellipedia, a Web application which allows analysts from different departments to post, read, and edit information on security intelligence.

Recent advances in IT have allowed government and other investigators to make use of a special form of data analysis known as data mining. Data mining uses computerized analysis, including statistical modeling, mathematical algorithms, and machine learning techniques, to derive patterns and relationships from data. In contrast to standard data analysis, which may only seek to prove or disprove a hypothesis provided by the user, data mining generates hypotheses that the user must then verify.[28] Thus, for example, a data-mining program might discover that an individual has a relationship to an extremist organization or matches the profile of a known terrorist; however, an investigator must still determine the validity of the match.

U.S. government officials have used data mining for a wide variety of objectives, including monitoring financial transactions and preventing terrorists from obtaining financial support. The U.S. Department of the Treasury's Financial Crimes Enforcement Network (FinCEN) investigates terrorist financing and money laundering using activity reports filed electronically by financial institutions. Law enforcement agencies can access FinCEN financial data directly over a secure Internet connection.[29] Financial institutions also search their accounts for potential matches to names on government investigative lists and notify FinCEN if they find a match.[30]

Other countries have made similar efforts to stop terrorist financing and prevent money laundering. In Germany, the Federal Criminal Police Office monitors suspicious financial activity and reviews electronic databases to ensure banks comply with antiterrorism laws.[31] Australia has also launched similar initiatives through its Australian Transaction Reports and Analysis Centre (AUSTRAC), which is an anti-money-laundering and counterterrorism financing organization. The Data Mining and Research Unit of AUSTRAC uses data-mining techniques to proactively and reactively analyze and monitor finance transactions to uncover hidden patterns.[32] In addition, the Office of

National Security in Australia has funded antiterrorism grants to develop enhanced data-mining tools.[33]

Data-mining efforts have led to the capture of suspected terrorists. Following the 9/11 attacks in the United States, the U.S. Department of Treasury worked with the Central Intelligence Agency to gain access to financial records from Swift, a Belgian banking cooperative that processes more than 11 million transactions a day between 7,800 financial institutions around the world.[34] Armed with this financial data, government investigators have discovered ties between known terrorists, domestic terror cells, and the extremist groups financing them. As an example, government investigators' analysis of data from Swift led to the capture of Riduan Isamuddin, the suspected mastermind of the 2002 Bali resort bombing.[35]

To use data mining, government agencies must be able to share data. Governments around the world have launched multiple data-sharing tools to improve collaboration between their law enforcement agencies and to share data on investigations and criminals. In Germany, for example, government groups have come together to develop a central database of extremists suspected of terrorism to improve coordination between law enforcement agencies.[36] In the United States, the FBI now can access data from multiple sources via the Investigative Data Warehouse (IDW), which combines data from the FBI's records and criminal case files with information from the U.S. Treasury Department, State Department, and Department of Homeland Security. Launched in 2004, the IDW saves significant time and effort for FBI agents, who can use it to complete a search of a thousand names of potential suspects in 30 minutes.[37] An equivalent search without the IDW would require FBI agents to query 15 different databases and waste thousands of hours of time. IDW allows FBI agents to link and cross-match names, Social Security numbers, and drivers' licenses across hundreds of millions of records.[38]

Preventing and Detecting Crime

Beyond playing a role in protecting the homeland against terrorism and external threats, IT plays a key role in ensuring public safety from domestic threats such as crime. Law enforcement agencies focus a large part of their efforts on proactive initiatives intended to prevent and detect crime. To be effective, agencies must thoroughly understand their community and the nature of crime within their jurisdiction. IT provides law enforcement with tools to capture, analyze, and present this information in a meaningful format. In addition, IT automates many of the time-consuming tasks associated with police work and frees police resources to be used on other effective programs. Some police departments have been quick to adopt technology to help their officers in the field. In the United States, the police department in Alexandria, Virginia, began giving its officers wireless handheld computers as early as 1997 so that they could access and report important information while on patrol, on a stakeout or at the scene of a crime.[46] Police officers of the future will be just as likely to carry a computer as they will to carry a gun.

Remote Monitoring

Law enforcement officials use various forms of remote monitoring as a tool to reduce crime and rehabilitate offenders. Remote monitoring acts as a deterrent because offenders know that they will be caught if they commit a crime or violate their parole. Police can also use remote monitoring to investigate crimes and eliminate suspects who can provide an electronic alibi. In addition, communities save money by using remote monitoring of offenders as an alternative to more expensive punishment such as incarceration while also allowing offenders to become productive members of society.

One form of remote monitoring uses global positioning system (GPS) technology. Law enforcement officials can use tamper-resistant GPS-enabled devices to track the movements and location of offenders sentenced to house arrest. Police and parole officers can either track individuals in real time using GPS-enabled devices (such as ankle bracelets) with transmitters or create a time-stamped log for later review with passive devices. Using GPS devices for remote monitoring can reduce expenses and improve outcomes for the criminal justice system. Such monitoring provides an effective means of enforcing house arrest, even for sentences that allow certain authorized activities away from the home. Rather than being put in jail, some low-risk offenders can

Box 13-1: IT and the Fight Against Human Trafficking

Modern-day slavery takes a horrifying toll on its victims—primarily women and children—who suffer loss of liberty, physical and emotional abuse, and sometimes even death. Human trafficking claims millions of victims every year and contributes to organized crime and global health risks.[39] IT serves as an important tool to combat this cruel practice.

IT has provided an effective medium for modern-day abolitionists to organize, communicate, and raise awareness. A multimedia campaign produced by the MTV Europe Foundation that works to increase awareness and prevention of human trafficking through its television programs, online content, concerts, and media events, for example, is MTV EXIT. The program's Internet site helps at-risk young adults in Asia learn how to stay safe and report abuse, and connects teenagers in European countries and other parts of the world with organizations they can get involved with to end human trafficking. MTV EXIT reaches 300 million households in 25 different countries and is translated into 10 different languages.[40]

A number of IT initiatives to increase information sharing and coordination among antitrafficking nongovernmental organizations, government organizations, and other groups in southeast Asia have been supported by the Asia Foundation, itself a nongovernmental organization.[41] One such initiative is building a human trafficking Web portal to link the different antitrafficking organization throughout Thailand, Cambodia, and Laos. Nongovernmental organizations working in rural areas track missing persons, while nongovernmental organizations working in cities, which are often the destination of trafficked persons, maintain lists of victims seeking help. More information sharing between these groups could help resolve missing person cases and help victims of trafficking contact their families. Using a single, comprehensive missing persons website allows nongovernmental organizations to be more effective and find local organizations to help victims adjust when they return home.[42]

Another antitrafficking project in southeast Asia is the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Social Sentinel Surveillance Project. This project is linked to a geographic information system (GIS)—an information system for capturing, storing, analyzing, managing, and presenting geographically referenced information. The Social Sentinel Surveillance Project trains villagers, local nongovernmental organizations, and health workers in China, Myanmar, and Laos to collect and report information on the migration of local women and children in their community at risk for trafficking. Similar data are collected from interviews with sex workers in Thailand, and all of the data are geocoded. Thus, researchers can use a GIS program to analyze the data and better understand how victims are trafficked, to understand migration patterns, to predict areas of high risk based on socioeconomic factors, and to determine which interventions are most effective.[43]

Nongovernmental organizations need reliable data to raise awareness and convince policymakers of the need to direct resources to the problem of human trafficking. Unfortunately, because of mistrust between communities and law enforcement, victims may be reluctant to report trafficking. In Cambodia, the Cambodian Women's Crisis Center is developing a database to collect and track information on the nature and scope of trafficking.[44] Similarly, the International Organization for Migration collects data on the victims it assists in the Counter-Trafficking Module Database. UNESCO has created a Trafficking Statistics Project website with the goal of assembling a comprehensive database of trafficking statistics and their corresponding methodologies.[45]

be required to stay at home, except to go out to work where they can make money to help pay for victim restitution. The cost of incarceration can cost a state approximately $25,000 per inmate per year, whereas the cost of remotely monitoring an inmate can cost less than $5,000 per year.[47] GPS-enabled devices also help monitor high-risk offenders. Law enforcement can use a computer to draw exclusion zones for sex offenders so that an alert will be sent out if the offender enters a restricted area such as a playground or school. GPS devices can similarly be used to enforce restraining orders. Thus, for example, if domestic violence offenders violate restrictions on visiting their spouse at their home or place of work, the police will be notified in real time.[48]

Law enforcement officials have turned to other electronic devices to monitor offenders with substance abuse problems. Many alternative sentencing programs require participants to cease using drugs or alcohol for the duration of their rehabilitation program. Traditional drug and alcohol testing involves supervised urine collection which must then be sent to a laboratory for analysis. There are new technologies that provide a more cost-effective alternative to this approach. One example is an alcohol-testing device that uses near infrared spectroscopy to measure an individual's alcohol level by examining a subject's inner forearm. Unlike traditional alcohol testing, this testing device can be used without supervision because the device uses biometrics to authenticate each person during the reading.[49] Another technology that counties in California have used to ensure that offenders in diversion programs are attending drug treatment counseling and parole meetings is a small plastic card embedded with the defendant's pertinent treatment information. County judges can easily monitor which offenders are meeting their obligations and which ones are not.[50]

Other IT-enabled devices can be used to make it harder for at-risk offenders to engage in criminal behavior. Although offenders' driving privileges are often suspended or restricted to reduce their threat to the community, studies have found that as many as 75 percent of all drivers with suspended licenses continue to drive.[51] Ignition interlock devices can prevent individuals from driving their cars if they have been drinking. An ignition interlock device requires the driver to blow into the device before starting the car; if the device detects a blood alcohol concentration in the driver above a certain threshold, then the car will not start. To help prevent cheating, the device continues to request additional samples from the driver at random intervals. An ignition interlock device also can be a useful tool to allow offenders to regain their driving privileges. In Ontario, for example, all individuals convicted of an impaired driving offense are required to have an ignition interlock device installed on their personal vehicles for a minimum of one year to retain their driving privileges; such individuals must pay for the cost of the device and bring the vehicle in for routine inspections.[52]

Other forms of remote monitoring are red light cameras and speed sensors to combat unsafe driving practices such as running red lights, speeding, and aggressive driving. Red light cameras have been deployed at dangerous rural and urban intersections to help reduce accident rates. Studies have found that equipping intersections with such cameras results in a decrease in right-angle crashes, accompanied by a fairly equal increase in rear-end crashes. (The increase in rear-end crashes may result because drivers are more likely to stop at a red light when it is equipped with a camera.) The net benefit of installing red light cameras is positive, however, because the injuries from rear-end crashes tend to be less severe than injuries from right-angle crashes.[53] In fact, using red light cameras reduces the total number of crashes with injuries by 25 to 30 percent.[54]

Remote-monitoring systems such as red light cameras and speed sensors to combat unsafe driving practices such as speeding and aggressive driving are important for two reasons: they stretch public safety funds further since police do not have to be engaged in this kind of routine work and they make people more aware that they will be more likely to be fined if they violate traffic laws. Government officials design smart traffic system not just to be punitive but also to promote safe driving.

Many remote-monitoring technologies target speeding. One in three traffic fatalities in the United States occurs because of speeding, and annually more than half a million people are injured.[55] Technologies like variable speed limit signs can automatically adjust the speed limit according to traffic flows, adverse weather conditions, or the presence of construction workers to improve driving safety.[56] In Herndon, Virginia, a speed-detection unit is connected to a traffic signal, so that if a vehicle is speeding, then the traffic signal will turn red; a street sign provides drivers advanced warning so they know that speeding will not get them to their destination any faster, thus promoting safer driving behavior.[57]

Digital Video Surveillance

For many years, law enforcement officers have used video surveillance—typically in the form of analog closed-circuit television (CCTV) cameras—to remotely monitor public places. Recently, however, police departments have been able to take advantage of the low cost of digital video cameras and wireless networks to develop large-scale, network-enabled video surveillance systems that allow officers to monitor high-quality video feeds and control multiple surveillance cameras in real time from a remote location. Wireless video cameras serve both as a deterrent to crime and as a tool for detecting and investigating crimes. Police departments can take advantage of the wireless cameras' portability and easily move the cameras to new locations to target crime hotspots. The initial results from many of these Internet Protocol (IP)-based video surveillance systems have been impressive. In Dallas, Texas, for example, the police department installed 40 IP-based digital video surveillance cameras in the city's central business district. The Dallas police department reported a 12 percent drop in crimes and a 9 percent increase in arrests in the first year after implementation of the system.[58]

There have been several high-profile projects that combined face-recognition systems with video surveillance to automatically identify individuals in a crowd, including projects at Boston Logan Airport, Keflavik Airport in Iceland, and the 2001 Super Bowl XXXV in Tampa, Florida. The objective with these systems was to have the CCTV cameras capture faces in a crowd so that they could then be matched to a database of known terrorists, criminals, and other wanted individuals. The projects had mixed success. In Tampa, the police department identified 19 people at the Super Bowl with outstanding warrants; however, it later decided to scrap a larger neighborhood surveillance program because the program did not make one match during a two-year pilot test of suspected criminals and runaway children.[59] In a three-month test of the system at Boston Logan Airport, the system correctly detected volunteers 153 times but failed 96 times.[60] Other airport trials combining face-recognition systems with video surveillance yielded similar results or were abandoned because of a high rate of false-positives.[61] Nevertheless, researchers expect performance of such systems to improve as the technology advances.

One of the largest deployments of CCTV cameras deployed throughout the nation, with over 4.2 million cameras, is in the United Kingdom.[62] In Birmingham and parts of London, British police have added face-recognition technology to CCTV systems to help combat crime. Although tests have found that the face-recognition technology failed to detect individuals on an alert list, the systems themselves have served as a deterrent to crime, and crime rates have dropped as much as 40 percent.[63] The CCTV systems were used by British investigators to investigate and identify the terrorists involved in the 2005 London subway bombings.[64] They have also provided valuable evidence to prosecute individuals accused of plotting to bomb the London subway.[65]

The police in the United Kingdom have extended the capabilities of video surveillance by adding automatic license-plate-recognition technology to track vehicles' movements. As digital cameras snap photographs of cars in transit, a computer logs each vehicle's license plate number along with the time, date, and location. A computer can then crosscheck these vehicles against police databases to verify that the vehicle has not been stolen, its tags are up to date, and it has insurance. Police expect the central database to be able to process up to 100 million plates per day.[66] Police in Seattle, Washington, use a similar technology in car-mounted cameras that alerts police officers if a nearby vehicle is stolen or on a watchlist. These cameras are capable of processing up to 1,000 license plates per hour.[67] The results can be dramatic: in 2007, a police officer in San Jose, California, arrested a suspect for kidnapping and forcible child molestation after his automatic license plate recognition system alerted him that the vehicle was stolen and used to kidnap a 12-year-old girl a day earlier. Had the system not been in place, the officer would probably never have stopped the suspect.[68]

Red light cameras have been deployed at dangerous rural and urban intersections; using these cameras reduces the total number of crashes with injuries by 25 to 30 percent.

Better Crime Analysis

IT allows police departments to better understand crime trends, manage their staff and resources and engage with their community.[69] Police departments of all sizes have adopted the CompStat management approach pioneered by the New York Police Department (NYPD). They use IT to collect and analyze crime and police data, then report on trends to gain better intelligence about crime and resource utilization. CompStat helped the NYPD implement its "broken windows" theory of policing that small crimes lead to big crimes. The CompStat method generates clear metrics that police department chiefs can use to hold police managers more accountable for their performance, validate the effectiveness of enforcement tactics, and rapidly respond to emerging crime trends.[70] Furthermore, by using CompStat in combination with an effective policing strategy, police departments can target specific areas that are hotspots for crime.

One important tool used by police departments that have adopted CompStat is crime mapping using GIS technology. Police departments process large amounts of data, with large departments processing thousands of crime incident reports every year, and the amount of data can be overwhelming. Although data from sources such as crime reports provide critical information, police departments need tools to manage the flow of information. Crime mapping uses IT to help police officers process crime incident reports by creating a visual representation of the crime committed within a certain geographic area over a certain time period. When police officers start a new shift, therefore, they can quickly review a map of recent crime incidents from their jurisdiction.[71]

Other available GIS applications can be used by police departments to conduct temporal and spatial analyses of crime data to identify trends, track serial offenders, and target hotspots for crime prevention. A prime example is CrimeStats, a spatial statistics software program developed by the National Institute of Justice, the research arm of the U.S. Department of Justice, and made available for free to police departments and researchers. Using CrimeStats, police can better identify high-crime areas and conduct geographic-profiling to target serial offenders.[72]

Some police departments use gunshot locator systems to automate the reporting of gunshots and to combat gun-related crime. Many times, gunfire goes unreported by citizens, especially those who have become accustomed to the noise. Yet gun-related crime affects the public safety of many communities. In 2004, 66 percent of the homicides in the United States were committed with guns.[73] The core of the gunshot locator system is a network of wired and wireless sensors spread across a city or along a highway. When gunshots are fired, the system can analyze the acoustics to determine the precise location of the shooting and even the direction the shooter is moving. The sensing system is integrated with mapping tools to provide law enforcement real-time visual information about gunfire within a certain geographic area. When gunshots are fired, the system immediately transmits this information to a response center, allowing police to respond within minutes. The real-time alerts provided by gunshot locator systems improve the ability of police to arrest criminals and provide medical aid to gunshot victims. After installing a gunshot locator system in Los Angeles County, the sheriff's department found that citizens were reporting only about 11 percent of gunfire that occurred. The information provided by the gunshot locator system allows police departments to better patrol gun crime hotspots and to target these areas with antigun programs.[74]

Police use crime mapping software to process crime reports and create a visual representation of the crime committed within a certain geographic area over a certain time period.

Responding to Crime

Communities want safe neighborhoods with low crime rates, and they have overwhelmingly turned to IT for solutions. When criminals strike, police need the tools necessary to provide an effective response. By using IT, a police force can be more productive, solve more crimes, and better protect the lives and property of the public. Law enforcement agents rely extensively on IT for criminal investigations, hazardous operations, and communication networks.

Biometrics and DNA in Law Enforcement

Biometric information for uniquely recognizing humans based upon one or more intrinsic physical traits includes fingerprints, images of the face, iris and retina, voiceprints, and DNA. Criminal investigators have long relied on biometric measurements such as fingerprints to identify suspects using evidence from a crime scene. Such information has served investigators in two ways: allowing them to verify that a known suspect was at the scene of a crime and helping them identify suspects on the basis of biometric evidence found at the scene.

In recent years, IT has taken biometric identification to an entirely new level. Using programs such as the Automated Fingerprint Identification System, for example, investigators can collect a set of fingerprints at a crime scene electronically using a mobile device and then compare them against a database of millions of fingerprints within seconds. Furthermore, biometric data such as fingerprints, images of the face, iris, and retina are increasingly collected by governments when they issue identification cards or passports. Consequently, criminal investigators now have national and international databases of digital biometric data at their disposal to search for and identify suspects.

For convicts, some countries collect biometric data such as DNA samples, which are more information-rich (i.e., have more distinguishing characteristics) than other biometric identifiers.[75] The United Kingdom, for example, has established a national DNA database, and police can collect DNA samples from any individual arrested for a crime just as they can collect fingerprints and mug shots.[76] France is working on a similar project to establish a national DNA database to track and identify terrorists and criminals.[77]

DNA has become an important link in the criminal justice system to solve crimes, identify missing persons, and protect the innocent. In the United States, for example, there have been 155 post-conviction exonerations using DNA evidence since 2000.[78] In addition, DNA can help law enforcement solve "cold" cases, thereby helping catch criminals who have managed to escape justice. New technology allows investigators to generate DNA profiles from existing evidence; and growing DNA databases give law enforcement officials a better chance of catching the criminal.[79] This approach helped identify the perpetrator of a series of brutal attacks and murders in North Carolina that had gone unsolved for over a decade. At the time of the crime, forensic DNA evidence indicated all of the crimes were committed by the same individual, but the police did not have any suspects. Ten years later, the police found a match to the DNA collected at the crime scenes after taking a routine DNA sample from an individual arrested for a shooting incident. When confronted with the DNA evidence, the suspect confessed to the attacks, thereby solving the case.[80]

Making it more difficult for criminals to assume false identities or fraudulently obtain government identity cards makes it easier for law enforcement officials to solve crimes and track criminals. Many governments and organizations have adopted IT to produce more secure identification cards to reduce the risk of fraud and forgery. As previously noted, many governments are now using e-passports to help secure borders. In addition, many governments have adopted sophisticated national or state identification smart cards that store biometric information such as a digital photograph, fingerprint, or retinal scan that makes it possible to definitively associate a particular person with an identity (name, date of birth, passport number, etc.). Imposters cannot conduct fraudulent transactions with a stolen ID card with biometric information, and criminals cannot assume fake identifies because their biometric signature will not match the one stored on the card.

The world's first smart national ID card is the MyKad developed in Malaysia. Developed by several agencies, including the Malaysian Road Transport Department, the Royal Malaysian Police, the Immigration Department, and the Ministry of Health, Malaysia's compulsory national ID card is designed to be a single authentication token for use in transactions with both government entities and private businesses.[81] Each smart ID card contains encrypted information about its owner, including e-cash balance, health information, driver's license information, passport information, and biometric data including fingerprints and a photograph. Malaysian citizens and permanent residents can use their smart ID card for many applications, including e-commerce transactions, e-banking, health care, and the use of public transportation.[82] Hong Kong has issued smart ID cards since 2003.[83] Spain moved to electronic IDs with biometrics in March 2006. For Spain, one of the principal goals of moving to electronic IDs was to create a secure platform for electronic signatures for everything from e-government to e-commerce.[84] Using electronic signatures allows individuals to complete legally binding transactions online (e.g., to sign a tax return).

Robotics in Law Enforcement

Law enforcement agencies use IT-enabled robots for a variety of tasks to assist officers and reduce their exposure to hazards. IT-enabled robots can be used by special weapons and tactics (SWAT) teams and bomb squads in dangerous operations to reduce the risk to human life. Law enforcement agencies around the world use robots for surveillance, the handling of hazardous materials, and bomb disposal. Law enforcement agents in the United Kingdom, for example, have relied since the 1970s on robots for bomb disposal in combating violence in Northern Ireland.[85] Robotic technology continues to advance and today's robots are portable, battery-powered wireless devices equipped with video cameras, microphones, and remote-controlled robotic arms. In fact, today's robots can climb stairs and curbs, open car doors, inspect under vehicles, and safely detonate explosives.[86]

Crime Scene Mapping

Crime scenes provide valuable information to help investigators solve crimes and prosecute cases. In the past, investigators have had to rely principally on two-dimensional drawings and photographs of crime scenes. A new technology called high-definition surveying relies on lasers and digital cameras to rapidly construct a detailed, three-dimensional computer model of a crime scene or accident. High-definition imaging systems provide two main benefits: they help investigators solve crimes and determine fault, and they help prosecutors explain a crime to the jury. The imaging systems work automatically: investigators set up the device in the middle of the crime scene, and the system automatically scans the surrounding environment. The imaging systems can be used indoors or outdoors, regardless of the amount of visible light, for surveying environments as small as an apartment or as large as a city block. Using such an imaging system, investigators can see exactly where evidence was found, zoom in on different locations, and manipulate the viewing angle to see the scene from any perspective. Thus, for example, a prosecutor can show members of the jury exactly what a witness would have seen looking into a building from the outside. Investigators can also create forensic animations to reconstruct a crime to better visualize a sequence of events.[87]

Empowering Communities and Victims of Crime

Police departments use a variety of IT-based tools to empower communities and victims of crime. In addition to using crime mapping for internal operations, police use crime mapping to share information about crime with the public. In Portland, Oregon, for example, the police department created a public version of its interactive crime-mapping tool and made it available to the community on a website. Citizens can use the website to generate maps of crime reports from the past 12 months; they can also sign up to receive custom alerts when certain crimes are committed near a given address. Police departments use crime-mapping tools on the Internet to alert the community to crimes, engage the public in solving problems, and ensure accountability for public safety efforts.[88]

Other IT-enabled tools are used to alert community members to possible threats, such as from likely repeat offenders. As an example, many communities require sex offenders to register in public databases so neighbors can remain vigilant against any dangers and take any necessary precautions. In addition, as of 2008, 34 states in the United States have some type of a statewide, automated victim notification system.[89] Victims and witnesses of a crime can register on such systems to receive alerts about the status of a particular inmate. IT-enabled victim notification systems make it easier for victims to be notified when an offender is released, transferred, or escapes from jail so that they can take steps to protect themselves. Such systems also offer psychological comfort to victims because they know they can access the state's prison inmate database online and reassure themselves that a particular inmate is still in jail.

Making Law Enforcement More Transparent

Using IT, government can make many aspects of law enforcement more transparent. Beyond allowing law enforcement officials to collect and analyze large amount of data, IT also allows this information to be shared with the public. Police departments that have computerized their incident and arrest reports can more easily share their data with nonprofit organizations and journalists. Using these data, researchers can monitor police performance and analyze the data for evidence of impropriety such as racial profiling. One city newspaper, for example, analyzed 480,000 incident reports from the Toronto Police Service's Criminal Information Processing System and reported evidence of racial profiling for certain charges and harsher treatment for offenders based on race.[90] Sharing data on incidents and arrests to the public can help police departments end improper practices and thereby build trust in the community.

Many police departments use electronic audio and video recording to create more transparency in the criminal justice system. Electronic recordings of police interrogations can provide valuable evidence to ensure the conviction of the guilty and provide an objective record. Studies have found that as many as 25 percent of false convictions can be at least partially attributed to wrongful confessions.[91] Electronic recordings can help protect the innocent and ensure that the true criminals are punished, help defend police against false accusations of impropriety, and help ensure justice for victims of police brutality.[92]

Although police departments have used video and audio records for many years, the recent move to digital video allows greater and more effective use of video technology. Digital video allows law enforcement officers to easily catalogue, archive, and share evidence among investigators. As an example, multiple police officers can monitor live streaming video of a police interrogation from their desktop computers or quickly access previous police tapes to review evidence. In addition, given the ever-increasing storage capabilities of today's computers, police departments can more easily store large amounts of digital video. This means that police departments can deploy video cameras widely throughout their operations. The use of car-mounted digital cameras, for example, ensures that citizens have a record of police encounters and can help improve community relations between police departments and the residents they protect.[93]

Finally, the IT revolution has equipped citizens with new tools to improve accountability in law enforcement. With so many cell phones now equipped with digital cameras, when a crime occurs witnesses are more likely to be able to provide digital evidence. Countless examples abound on the Internet of individuals who recorded questionable police action via a digital camera. In 2006, three separate incidents in Los Angeles were caught on video by ordinary citizens during a single week showing alleged police brutality.[94] Website like YouTube and CNN's iReport allow any individual with a camera to quickly share a video or photographic record with the media and the public.

Facilitating Emergency Communications

During an emergency, robust, flexible, mobile communication is essential to enable first responders such as police, fire, and emergency medical services to communicate with other emergency workers and coordinate their response. Unfortunately, many existing communications networks, including cellular phone networks, do not offer enough bandwidth or reliability for emergency communications and can be overloaded by subscribers during an emergency. Challenges related to interoperability can hamper interjurisdictional emergency response efforts. And good communications networks in rural areas may

High-definition surveying relies on lasers and digital cameras to rapidly construct a detailed, three-dimensional computer model of a crime scene or accident.

be destroyed during an emergency or nonexistent.[95] IT is helping to address these issues.

Public Safety Networks

To help their communities better prepare for an effective emergency response to accidents and natural disasters, many municipalities have developed state-of-the-art, regional public safety networks to protect the lives of first responders and the citizens they serve. Many technologies can be used for creating public safety networks including cellular, municipal wireless, satellite and existing analog television spectrum.[96]

Public safety networks enable public safety workers to use traditional voice communication but also allow them to access online resources and connect network-enabled devices. Thus, for example, police officers on patrol can use a wireless network to access the FBI's National Crime Information Center in the field to look up in real time fingerprint records, mug shots, and criminal histories.[97] Similarly, police officers can connect to their local police department network to complete routine tasks such as submitting crime reports and issuing traffic citations. Firefighters can use public safety networks to check traffic patterns and find driving directions on the way to a fire. Also important to firefighters is the availability of electronic building plans. Companies such as Be-Safe Technologies work with schools, governments, corporations, and residential communities to pull together—and when necessary generate anew—all the relevant information about buildings (floor plans, location of utility boxes, entries, etc.), then make that data available through an online interface accessible to emergency personnel. That way, when an emergency happens, the first responders will have all the information they need to know about a building, including real-time information like which fire alarms were set off, so that they do not have to enter a potentially dangerous situation blindly.

One pilot project in the United Kingdom demonstrated the benefits of a broadband mobile network for public safety. Using existing cellular networks, officers could access the police department network and stream video to headquarters.[98] In the United States, cities including Portland, Oregon, have achieved high levels of reliability and scalability in their public safety networks by using the architecture of a wireless mesh network. Wireless mesh networks use many nodes that act as both an access point for clients and part of the backend network routing infrastructure. This architecture is highly resilient to node failures, for example from bad weather, and allows city planners to easily increase capacity to meet new demand by adding more nodes. In addition, mesh networks can use network management techniques to ensure quality of service levels in an emergency for high-priority network traffic.[99]

The rise of Internet-enabled cameras has also enabled first responders to access more information when responding to emergencies in buildings because they can see what is happening on the ground even before sending in the initial team to determine the appropriate response and where the trouble areas are. Furthermore, the growing prevalence of high-bandwidth wireless connectivity means that such cameras can be accessed while on the move from inside police cars, firetrucks, and ambulances.

Police officers on patrol can use a wireless network to access the FBI's National Crime Information Center in the field to look up fingerprint records, mug shots, and criminal histories.

The Emergency Alert System

The Emergency Alert System (EAS) is a national public warning system in the United States that was put into place to give the U.S. president the ability to communicate with the American public in the event of a national emergency. State and local officials can use the EAS to address emergencies in their specific areas. Because traditional two-way communication networks can quickly become overloaded in a major emergency, the government must rely on broadcast networks to communicate with the public. The EAS is a public warning system for all broadcasters, including television, radio, and cable and satellite services. To allow the secure transmission of alerts in various formats, including text, audio, and video, the Federal Communications Commission (FCC) has defined a special messaging protocol to use on the EAS.[100] The FCC requires all participating broadcasters to have dedicated equipment that will automatically receive, decode, and retransmit messages sent through the EAS. It also requires that all EAS equipment be tested weekly. The National Weather Service uses the EAS to distribute emergency weather information to the public, and state and local officials use the EAS to distribute local emergency information.[101]

Currently, one important use of the EAS is to help locate missing or abducted children. State and local law enforcement can use the emergency alert system to broadcast an AMBER (America's Missing: Broadcasting Emergency Response) Alert to law enforcement and the media about a child abduction. The AMBER Alert system facilitates the rapid distribution of information on a child abduction to the public so members of the community can assist in the search and recovery of the child. AMBER Alert information includes descriptions of the child, abductor and any information about the abductor's vehicle. Television and radio stations voluntarily alert their audiences to the information and electronic highway billboards display the alerts for drivers. All cell phone subscribers can also register to receive geographic-specific AMBER Alerts as text messages on their cell phones.[102]

A new initiative, AmberView, would provide a tool to broadcast an abducted child's image to law enforcement, the media, and the public. Through this initiative, on the annual school picture day, parents can consent to having a high-quality digital photograph and updated biographical and physical information about their children stored in a secure database. In the event of abduction, law enforcement officials can use the digital image in this database to quickly distribute the missing child's photograph.[103]

The next generation of EAS is the Integrated Public Alert and Warning System (IPAWS), which will allow the transmission of alerts through multiple devices, including cell phones, pagers, radio, personal digital assistants (PDAs), road signs, and personal computers. IPAWS will also allow alerts to be sent in a variety of formats and languages, including in American Sign Language and Braille.[104]

Other Emergency Communications Systems

Enhanced 911. IT is especially vital to the communications networks that are the key to a successful emergency response to accidents and natural disasters.[105] In the United States and Canada, IT is used in location technology that enables emergency services to locate the geographic position of the caller—called enhanced 911 (or e-911). E-911 automatically associates an address with the caller's phone number and directs the call to the nearest Public Safety Answering Point (a county- or city-controlled agency responsible for answering 9-1-1 calls for emergency assistance from police, fire, and ambulance services). The dispatcher sees the caller's address immediately, saving the precious time it used to take to recite and enter that information and overcoming situations where the caller may be unable to provide their address because they do not know it or are distracted by the emergency.[106] This basic concept of e-911 has expanded into a second phase that uses either triangulation between cellular towers or the GPS capabilities built into many mobile phones to do the same routing for mobile callers. Thus, e-911 allows emergency personnel to find callers wherever they might be.

Websites and Wikis. IT also empowers communities to organize and respond to emergencies and natural disasters. Many communities have used the Internet during an emergency to coordinate recovery efforts and match the many individuals requesting aid to offers of assistance. After Hurricane Katrina hit Louisiana and Mississippi in the summer of 2005, websites such as Craigslist provided each community an open forum to exchange ideas and information. Animal rescue organizations used the Internet to locate pet owners, find new homes for animals, and reach out to donors. Volunteers working around the world established the KatrinaHelp Wiki as a clearinghouse for information on multiple recovery efforts. One major initiative, the Katrina PeopleFinder project, aggregated data about survivors from multiple sources into a single repository using an interoperable XML standard called the

People Finder Interchange Format. Volunteers could sign up to manually input data into the repository from unstructured data sources gathered by relief agencies, newspapers or employers. By harnessing the power of the Internet, volunteers were able to quickly enter data for over 640,000 Katrina survivors.[107] Family and friends could then search this database to find missing loved ones.[108] Other projects on the wiki helped victims find shelter, access health care, receive government assistance, and find jobs.[109]

Microblogging. Microblogging is another IT-enabled tool to help disseminate information during emergencies and natural disasters. Services such as Twitter allow users to post short messages about their activities. Although originally built as a tool for friends to keep in touch, Twitter has introduced a new avenue for finding information in real time. Thus, for example, during emergencies like the California wildfires and the earthquake in China, Twitter has proven its worth as a resource for real-time information. In China, news of the earthquake hit Twitter even before the U.S. Geological Survey, which is charged with giving early warnings about earthquakes, had any information on its website.[110] In California, when local news was overwhelmed and national news could only provide scant details, residents turned to Twitter for information about evacuations, meeting points, and places to gather supplies.[111] In both instances, because locals were microbloggers, an organic network of news gatherers came into being, providing real-time updates of what was actually happening on the ground, helping people react in the safest possible way and, by coordinating response efforts, likely saving lives.

Text Messaging. IT is revolutionizing the way humanitarian organizations provide relief in developing countries. As noted earlier, websites are increasingly used to facilitate communications during emergencies. Thus, it is not surprising that the United Nations' humanitarian affairs office has opened up a website called ReliefWeb. This website for the humanitarian relief community allows aid workers across the world to get up-to-date maps and data on emergencies and disasters around the world—everything from flooding to refugee migration.[112] Individuals affected by natural or other disasters can also use IT to obtain aid. In north Kenya, for example, a refugee with access to a mobile phone sent a text message to United Nations officials noting the lack of food in his camp.[113] Officials responded by increasing food distribution.

Humanitarian aid agencies are using IT in their operations both for emergency communications and to exchange information about supplies and deliveries.[114] Moreover, governments are beginning to see the value of using IT to reach their citizens before disaster strikes. The government of Sri Lanka, for example, has an early-warning system that sends short message service (SMS) messages to every mobile phone in an area at risk of flooding.[115]

Coping with Accidents and Natural Disasters

Governments and nongovernmental organizations are using IT to predict, respond to, and manage accidents at dangerous facilities, as well as natural phenomena such as hurricanes, wildfires, tsunamis, and landslides. Using satellite images, aerial photographs, and on-the-ground inspections, such organizations can locate populations in dangerous or environmentally unstable places and determine how to respond after disaster strikes.[116] The Respond Project, for example, used geographic information system (GIS) data on India and Sri Lanka after the 2004 tsunami to plan improvements in preparedness and prediction.[117] Similarly, a United Kingdom charity, MapAction, responded quickly to several disasters by providing mapping and GIS experts to identify key facilities such as hospitals, food warehouses, and roads. These data were incorporated into digital maps and distributed to relief organizations working in the areas.[118]

Preventing and Dealing with Accidents

Even with comprehensive security controls at dangerous sites such as chemical plants, nuclear power plants, and refineries, use comprehensive security controls, no site is immune to all accidents. When accidents occur at such sites, one goal of emergency responders is to determine if the disaster has created any new threats. In the United States, the National

Atmospheric Release Advisory Center (NARAC) monitors the release of hazardous material into the atmosphere. NARAC provides tools to model and predict the spread of airborne particles from nuclear, radiological, chemical, biological, or natural emissions. NARAC has developed a distributed system that provides three-dimensional modeling of hazards using geographic data and real-time weather information. Using this system, emergency responders can produce initial predictions within minutes and then refine these predictions as new data becomes available from the field. NARAC also provides a tool to map the spread of hazards so emergency workers can notify and protect the affected communities.[119]

Other tools allow researchers to spot and prevent human-made disasters before they happen. Aviation experts working for airlines, for example, regularly comb through large amounts of data collected from computer records of daily flights and pilot incident reports to spot potential hazards, such as areas on the ground or in the air at higher risk of collision. In the United States, the Federal Aviation Administration has even launched a data-mining effort to detect anomalies in data recorded in-flight, including airspeed, pitch angles, engine temperatures, and movements. These efforts ensure that aviation experts can learn lessons not only from past mistakes but also from "near misses" that might reveal some safety flaw.[120] Engineers similarly use IT to study and improve the structural integrity of buildings and bridges. To study the impact of earthquakes on building materials, one university research group at SUNY Buffalo built a complete two-story house on top of an earthquake simulator. The researchers then collected data from 250 sensors spread throughout the house and a series of video cameras. Analyzing these data will enable engineers to construct more stable buildings.[121]

Forecasting Hurricanes

Hurricanes can be incredibly deadly and destructive through a combination of high winds, heavy rain, and large waves. Public officials can mitigate some of the loss of life and destruction from a hurricane if they can accurately predict the hurricane's size and wind speed and when and where the hurricane will make landfall.

Advances in IT have enabled the collection of more precise hurricane data. Much of the information used to track hurricanes in the United States comes from the Doppler radar network established in the 1980s by the National Oceanic and Atmospheric Administration (NOAA). In addition, forecasters use geostationary weather satellites to obtain measurements of hurricane activity and intensity, even in remote ocean areas.[122] To get more detailed information, scientists fly special aircraft into or around the storm to take precise measurements about the structure and intensity of the hurricane. In addition, the scientists release GPS-enabled dropwindsondes, special instruments deployed from the aircraft that drift down on a parachute measuring vertical profiles of pressure, temperature, humidity, and wind as they fall to the earth, and then radio the information back to the scientists.[123] A new technique, recently developed by NOAA has found that computer models can accurately predict a storm's intensity from sound sensors as a hurricane moves in the ocean.[124]

Once forecasters collect hurricane-related data from radar and satellites, they can use computer models to predict a hurricane's movement. Much of the impact of a hurricane comes from coastal and inland flooding, particularly flooding caused by the storm surge. Forecasters use tools such as the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model to make precise predictions about flooding based on the latest hurricane data information and information about the coastal terrain. Such models allow public officials to warn and evacuate communities who are most likely to be impacted by a hurricane.

Forecasters use software tools to make precise predictions about flooding based on the latest hurricane data information and information about the coastal terrain.

Predicting and Responding to Wildfires

Wildfires ravage thousands of acres of land every year, destroying homes and businesses and killing firefighters, civilians and wildlife. Scientists use IT to help them better predict, manage, and respond to wildfires. They can use dynamic data-driven computer models, for example, to predict a wildfire's progression and help firefighters determine the best response. The mechanics of a wildfire are enormously complex and can be influenced by anything from the weather to the chemistry of the fuel. To accurately predict wildfire behavior, computer models must consider many complex processes and incomplete data sets, a challenge to which today's supercomputers are finally able to respond.[125]

Scientists collect data for wildfire modeling from satellites, aerial photography and surveying, and remote sensors. Remote sensors that can survive low-intensity fires, such as Web-enabled surveillance cameras and fixed autonomous sensors for detecting environmental conditions, offer the potential for real-time updates to firefighters.[126] Such remote sensors can collect measurements such as temperature, wind direction and speed, and moisture levels; send this data to be processed by a computer; and then transmit wildfire prediction maps to the handheld computers of firefighters on the ground.[127] Wildfire prediction information sent to their handheld computers can help firefighters on the ground avoid injury from changing wildfire conditions and allow them to evacuate the most threatened areas.

Geographic information systems (GIS) also enable better data collection and representation. By making it possible to associate data points with specific spatial locations on Earth, GIS make it possible for scientists to more accurately model wildfire behavior and visually represent wildfire predictions on maps such as Google Earth. Firefighters on the ground are also making use of GIS to coordinate and improve their response. Firefighters can use GIS to quickly locate resources such as water or identify locations at risk such as schools.[128] Special technology exists for firefighters to help them locate each other on the scene of the fire and to better monitor firefighters' vital signs and locations. This technology facilitates communications between firefighters and the command center.[129] In addition, firefighters can use handheld computers to record environmental factors, run hydraulic calculators, and predict fire behavior. They can also use handheld computers to consult electronic medical references and emergency translators for access to common medical phrases.[130] Finally, firefighters and ambulance drivers can use GPS to get to locations where they are needed and to locate the nearest hospital.

Detecting Tsunamis in Time to Provide Warnings

Events such as volcanic eruptions, landslides, earthquakes, or even impacts by an asteroid can rapidly displace water to trigger massive ocean waves known as tsunamis. The devastating power of tsunamis was brought to light in 2004 when an earthquake off of the coast of Sumatra generated a tsunami in the Indian Ocean that resulted in the deaths of 230,000 people and displaced millions.[131] The hardest hit countries were Indonesia, Sri Lanka, India, and Thailand.

Tragically, the fact that the Pacific Tsunami Warning Center lacked some of the newer tools to accurately predict the risk of a tsunami hampered early warning efforts for the 2004 tsunami. Using seismological data, the Pacific Tsunami Warning Center initially estimated that the tremors only reached a magnitude of 8.0 rather than the actual magnitude of 9.1. Other computer models could have better gauged the magnitude of the tremors. Within two hours of the quakes, a computer at Harvard University in Massachusetts accurately predicted the higher magnitude of the tremors from the same seismological data; unfortunately, however, that computer was not equipped to send automatic alerts to the Pacific Tsunami Warning Center.[132]

Since 2004, public officials have invested in a more complete early warning system to detect tsunamis and alert coastal areas to a tsunami threat. The result is an international Tsunami Warning System, a network of seismometers, sea-bottom pressure sensors, and tide gauges that continually monitor, collect, and share data on oceanic activity. In addition, coastal areas have invested in better alert systems so public officials can quickly notify communities of a threat.[133]

Predicting Landslides

Landslides pose a serious threat to many urban and rural areas, causing more than $1 billion dollars in damages and over 25 deaths every year in the United States alone. Although landslides are triggered by other natural disasters, such as earthquakes, volcanoes, wildfires and floods, public safety officials can help reduce losses from such events by identifying landslide hazards and developing mitigation strategies.[134]

IT has played a major role in improving the identification of landslide hazards through the use of advanced modeling and simulation tools and the growth of GIS technology. Landslides are influenced by many complex factors which can be difficult to measure including vegetation type, terrain alignment, soil cohesion and depth to water table. Although scientists are still far from developing complete hazard models, they have improved their techniques for risk assessment. Thus, for example, geologists can use digital elevation models and the related software tools to better understand the terrain and surface topography, which strongly influences the risk of a landslide. In addition, scientists can use GIS-based quantitative and qualitative modeling techniques to more accurately predict landslide susceptibility and generate hazard maps.[135]

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14. Goverment

One of the pillars of every community is its system of government. Many government functions, such as collecting taxes and running elections, involve the collection and dissemination of information. Thus, governments can use information technology (IT) to solve a host of problems.

Because IT facilitates the collection, analysis, and distribution of information, its use penetrates all layers of government and government agencies regardless of size or mission. Governments can use IT for mission support. Governments can use electronic record management systems to help ensure secure data storage, easier access to information, and more accountability. Governments can also use IT to reduce operational costs by, for example, implementing telework and teleconferencing solutions to save money on office space and travel expenses. In addition, governments can develop large-scale IT solutions to address specific problems such as border control, national defense, law enforcement, and health care. In fact, the possible applications for IT in government, just as in industry, are nearly limitless.

For each tax return filed electronically instead of on paper, the IRS saves an estimated $2.15 per return and the error rate declines from 20 percent to under 1 percent.

Although e-government's potential still remains largely untapped, a whole host of benefits can already be seen among technology-savvy agencies at all levels of government. As discussed below, some governments have used IT as a catalyst for modernizing government and improving the efficiency and quality of government services. In addition, some governments have transformed themselves and empowered their citizens by streamlining their activities and processes to facilitate citizens' access to information, as well as by creating more openness and transparency in government operations to allow better public oversight.

Making Government More Efficient

A primary use of IT in government is to improve the efficiency of government operations. Although the scale and scope of projects vary, the productivity benefits gained when government agencies adopt IT to improve efficiency translate into direct savings for taxpayers or better allocation of government resources.

The idea of using IT to track various performance indicators in government was pioneered when Baltimore Mayor Martin O'Malley implemented CitiStat, a program that uses IT for a real-time data-tracking and management tool to help manage the city government's performance. By using IT to track various performance indicators such as employee absenteeism and overtime, the city of Baltimore eliminated $13 million in unnecessary government spending in the first year of the CitiState initiative.[1] Later, when O'Malley became governor of Maryland, he created the similar StateStat program to help manage the state government, as well as the BayStat program to assess progress on revitalizing and protecting the Chesapeake Bay.[2]

Just as businesses use IT to cut costs, in part by encouraging customers to use low-cost service delivery channels like the Internet, so too is government using IT to cut costs. In the United States, the U.S. General Services Administration's online purchasing and acquisition system—GSA Advantage!—yields savings of $90 to $240 in administrative costs per transaction compared to manual purchase orders.[3] Similarly, the Internal Revenue Service's (IRS) single point of access for free online tax preparation and filing services by private companies—the IRS Free File system—has saved millions of dollars in processing costs for the almost 20 million tax returns that have been filed electronically since the program's inception in 2003.[4] For each tax return filed electronically instead of on paper, the IRS saved an estimated $2.15 per return, and the error rate on returns submitted declined from 20 percent for paper returns to under 1 percent for electronic returns.[5] In addition, because the private companies performing tax preparation and filing services are competing intensely for market share, they have strong incentives to make their programs as easy to use and comprehensive as possible.

The success of the partnership between the IRS and online tax preparation and filing services illustrates an important point: IT solutions for government do not necessarily need to be operated by government. The private sector routinely uses IT to enable partnerships and outsourcing to enhance innovation and cut costs. The United Parcel Service, for example, uses its extensive transportation and IT network to run the logistics operations of many companies. Governments can also move beyond engaging with companies simply as e-government vendors and instead empower third-party for-profit and nonprofit organizations to act as partners in the provision of e-government services.[6] The U.S. Library of Congress, for example, decided to make available thousands of photos from its archives by partnering with the commercial online photo sharing service Flickr rather than build its own online photo archive.[7]

Governments also can become more efficient by developing applications that build on existing private-sector tools. In Washington, D.C., for example, the city's chief technology officer found that rather than spending millions on an enterprise system, the city in some cases could take advantage of free Web-based tools such as Google applications, open-source tools, and low-cost Web-based software to rapidly deploy new government applications for citizens and collaboration tools for its employees with less cost to the city.[8] At the state level, the Alabama Department of Homeland Security built a central online repository of county data, maps, and imagery and integrated the information with Google Earth, a virtual globe application. Dubbed "Virtual Alabama," the online system is a digital clearinghouse for government maps, photos, and logistical information on all 67 of the state's counties that allows state and federal government agencies to quickly access that material. First responders, for example, can use the "Virtual Alabama" system to survey damage before, during, and after a disaster for operational planning, asset tracking, and critical infrastructure mapping.[9] By integrating all of this functionality and data into a single online application that serves the needs of multiple agencies, the state government spread the cost of the system across multiple partners. Moreover, by creating an easy-to-use platform for data sharing and collaboration, the state has created an incentive for counties to create and share better data.

Providing government services online, a form of e-government, can often provide significant savings to governments and government service users. The renewal of a driver's license, for example, costs the government about $1 if done online, whereas it costs about $8 if done in person. Many e-government initiatives allow citizens to interact with government through the Web, thereby saving taxpayers money and often improving service. As an example, the Kansas Highway Patrol put crash logs on a website called Online Crash Logs, thereby streamlining the process of recording and distributing crash information by reducing the amount of paperwork dispatchers must complete and also by greatly reducing the number of phone calls from the public and media; now the media and public can check crash logs often and view the most current, accurate crash information without impeding the daily operations of the dispatchers.

Improving Government Services

IT is used not just to improve the efficiency of government services but also to improve the quality of government services. IT is especially useful at improving government efficiency and reliability in large-scale applications for basic government functions, such as running an election, conducting a census, and collecting taxes. By automating a variety of tasks, government agencies can increase productivity and improve the quality of services delivered to citizens, businesses, and other government entities.

Many governments around the world have adopted IT to improve their voting processes for the simple reason that computers can count much more reliably than humans. The technology used in voting varies by jurisdiction. It ranges from touchscreen electronic voting machines to optical scanners for paper ballots[11] and even includes an Internet voting platform developed by the Republic of Estonia to increase voter participation and convenience.[12] Internet voting is particularly promising for voters living abroad who might otherwise not be able to participate in elections. In Florida, for example, the Operation BRAVO Foundation is working with Okaloosa County to create an Internet-based voting system for the 20,000 active duty military members who vote in the county but are currently living abroad.[13] Many national statistics agencies have invested in IT to more efficiently collect, process, and distribute survey data in their national census. Statistics Canada, for example, provides multiple online tools to allow researchers to access and manipulate survey data and in 2006, 19 percent of Canadians responded to the census questionnaire online.[14]

Investments in IT often benefit citizens directly in the form of improvements in government services. Initiatives like the CitiStat program in Baltimore allow managers to better track the performance of basic city operations such as trash removal, street repairs, and snow removal. CitiStat also tracks calls by residents to a 311 non-emergency complaint call center, so government officials can identify trends and ensure departments appropriately respond to requests.[15] In New York City, when residents contact 911 or 311, they can also submit pictures and video to the call center to help record their complaint. A website opened by the government of Italy, Denuncia vi@Web, enables citizens to report a crime online. This simplifies the process citizens use to report crime by reducing the amount of paperwork and also makes it possible to report a crime anywhere at anytime.[16]

Other uses of IT simply make government more customer-friendly. In Virginia, for example, residents can log on to the Department of Motor Vehicles website to check the wait time for service at regional offices to decide when and where to go. Once government successfully digitizes information, it can focus on developing the most effective tools and applications to meet the needs of citizens. A pilot project in Belgium called Multigov is evaluating different platforms to allow government-citizen interactions outside of the traditional face-to-face, telephone, and Internet by branching out into emerging areas such as electronic kiosks, interactive digital television, and mobile services.[17]

E-government initiatives that streamline government functions also can benefit businesses and save them money. Often government regulatory hurdles impose significant costs on businesses and decrease productivity. At one time, for example, starting a new company in Beijing required an application to eight government agencies and the coordination of multiple in-person meetings. In 2000, Beijing's mayor launched an initiative called Digital Beijing to simplify the application, reporting, and administration processes. Investors in Beijing can now conduct all of these activities from a single website that shares information across multiple agencies.[18]

Governments elsewhere have adopted IT systems to improve business-government interactions such as processing imports and exports. In the Philippines, for example, the Customs Bureau invested in an IT system to automatically process import clearance documents, payments, and release orders for shipments. By automating this process, the Customs Bureau eliminated many of the bureaucratic delays and corruption that had mired their paper-based system.[19] In the United States, the state of Ohio established an e-tax reporting system that lets business taxpayers enter information common to all municipalities once, and then automatically distributes the information to all appropriate entities. Previously, businesses had to understand and comply with a patchwork of requirements and processes across the range of municipalities in which they conduct business.

Governments can also use IT to more effectively use their natural resources. Alabama's Office of Water Resources has launched an initiative to create a digital map of the state's waterways using global positioning system (GPS) technology. Using this information, state officials will be better able to protect waterways during natural disasters such as hurricanes or droughts and plan statewide water resource allocations. The GPS data may also facilitate the state's industrial recruitment by showing perspective firms exactly where water resources are located.[20]

Facilitating Citizens' Access to Information

Governments are using IT to empower citizens by facilitating their access to information. The U.S. Government Printing Office, for example, provides online access to databases containing the full text of public documents produced by the three branches of government. In addition, the U.S. General Services Administration runs USA.gov, a national portal for government services. Similar portals for online government services can be found in many other countries. In the United Kingdom, Directgov provides a portal to public services of the government, and the National Archives is home to multiple online databases of digitized public documents including government publications and historical documents dating as far back as the 8th century such as census records, immigration documents, family records, and military records.[21]

IT enables legislators and citizens around the world to discuss best practices and policies. An online clearinghouse of policy ideas called e-Parliament, for example, helps connect legislators with experts on global problems and legislative solutions employed by different governments to address various problems. Their first poll on energy issues engaged 600 legislators from 63 countries.[22]

Government agencies can use IT not only to increase access to public records but also as a platform to distribute a whole host of educational materials online—from history and civics lessons to medical information to information about government services and initiatives available to their citizens. In the United States, for example, the Small Business Administration provides a wide array of resources, training and tools on its website to help citizens launch, manage and grow their businesses.[23]

Even governments in the less developed countries can use IT to help increase access to information. In rural Sri Lanka, most community members are prevented from using the Internet to get information by barriers such as the lack of access to computers and the Internet, digital literacy, and language. To respond to this challenge, Sri Lankan government ministries helped form the Kothmale Community Radio Internet Project—an interactive radio program that provided listeners a virtual Internet browsing experience. Broadcasters browse the Internet on behalf of their listeners and then explain and discuss the information with guests (e.g., a doctor might be invited to explain information on a health website).[24]

IT is also improving communication between citizens and government through Web-based interactions. At a local level, residents in many jurisdictions can report problems such as potholes in the road or broken fire hydrants through Web-based forms or by editing citizen-generated maps online. Citizens can use e-mail to contact their representatives and voice their positions on legislative proposals or other issues of concern. In Dubai, for example, the Roads and Transport Authority (RTA) has created AskDubai, an online service that allows citizens to request information on RTA services, make department inquiries, and report problems.[25] In the United Kingdom, a website linking U.K. citizens and their government called My Society has a program called Fix My Street that enables the public to coordinate with others in their community and their local Member of Parliament to solve neighborhood problems such as graffiti and to repair roads.[26] Similarly, citizens in Los Angeles can use an online application to report recent tagging incidents, providing on-the-ground intelligence to officials in charge of abatement and making their graffiti mitigation programs more comprehensive, cost-effective, and efficient.[27]

IT is also helping to automate government services that previously required bureaucratic hassles, such as requesting government documents. In Austria, for example, citizens no longer need to request birth or marriage certificates. The country's e-government registry automatically forwards the necessary information to the appropriate agency.[28] Government agencies and officials also rely on technology to communicate with their customers and constituents by using websites, e-mail, and syndicated news feeds (e.g., using RSS formats). Government agencies have also established online forums to foster discussion on policy proposals between citizens and government officials and created blogs to provide a more direct window into government

Initiatives like the CitiStat program in Baltimore allow city managers to better track the performance of basic city operations such as trash removal, street repairs, and snow removal.

Promoting Government Transparency and Accountability

Recent advances in IT enable citizens to hold government officials more accountable for fraud, waste, and abuse. Before the Internet, citizens had few resources to learn about the myriad government agencies and services available to them or about the effectiveness of various government programs. Governments were held accountable primarily by professional journalists or internal government reviews. The Internet has changed everything by making it possible for governments to operate more openly and with more citizen oversight.

In recent years, more and more government agencies have created a Web presence and given citizens the opportunity to review their budgets, accomplishments, and practices. In Colombia, for example, the president led an e-government initiative to establish useful websites across the federal government with the purpose of increasing accountability; in less than a year, almost every government agency in the country had a website containing the agency mission statement, contact directories and budget information and the federal government had launched a central government portal.[29] In 2007, Google partnered with California, Virginia, and other states to implement a new site map protocol that makes all search engines more effective in indexing information the states had made available online but had been difficult to find.[30]

IT can also make information about government oversight more timely and relevant. By creating the electronic financial disclosure system EDGAR, the U.S. Securities and Exchange Commission has been able to streamline the collection and dissemination of company information on regulatory compliance to investors, companies, and third parties.[31] The Web-based EDGAR system not only decreases bureaucracy but also puts financial data in the hands of ordinary investors. An annual subscription to EDGAR costs less than one-sixth what a subscription to the information cost prior to electronic collection. In addition, research has shown that the added transparency afforded by EDGAR has affected the stock market: when the electronic fillings were first published, stock prices changed dramatically as fund managers incorporated the new information into their pricing predictions.[32]

Increased openness and transparency helps ensure proper oversight and reduces government waste. Thus, some governments have used e-procurement systems to increase supplier choice and reduce corruption. In Chile, for example, government agencies had no standardized procurement process prior to 2003. That year, the Chilean government launched an e-procurement initiative called ChileCompra to make the procurement process more transparent, efficient, and accessible. The government posts procurement announcements on a website, and the results of all bids are posted online. In 2007, Chile reported that over 900 agencies had used the ChileCompra system to conduct USD $4.5 billion in transactions. Businesses benefit from increased access to the government market. The government even established 16 regional "entrepreneurial centers" to help small businesses gain access to this market.[33] The Chilean government also benefits from increased competition and saves approximately USD $50 million annually in public expenditures.[34]

In many countries, IT has actually reshaped the influence of money in politics. Until recently, citizens could do little to lift the veil on campaign financing. Even with campaign finance disclosure laws, few individuals have the resources to wade through stacks of filings to discover who has sponsored individual candidates, political parties, or political organizations (e.g., political action committees). Countries that have adopted electronic filing and reporting requirements for campaign contributions provide much more transparency in the political process. In the United Kingdom, for example, the Electoral Commission provides a searchable database of campaign contributions and expenditures of candidates and parties. In the United States, similar information is provided by the Federal Election Commission. In addition, nonprofit organizations have developed websites such as OpenSecrets.org and FollowTheMoney.org that provide citizens with tools to better understand this government data by, for example, allowing them to easily find who

Websites such as WikiLeaks.org provide whistleblowers an untraceable forum for anonymously posting documents that expose unethical behavior or oppressive regimes.

in their neighborhood has donated to a particular political candidate.

Sometimes, when citizens do not feel the government has created enough openness and transparency, nongovernmental organizations have launched IT-based projects to increase accountability. In the United States, projects such as the National Security Archive have created an online, searchable archive of declassified government documents relating to national security, foreign, intelligence, and economic policies that have been previously unreleased.[35] Another project, Open CRS, provides an online database of Congressional Research Service reports that are otherwise unavailable to the public.[36] The website LegiStorm provides information on Congress such as salaries of members and staff, privately financed trips, foreign gifts and financial disclosures.[37]

The Sunlight Foundation has set up a website that serves as a clearinghouse for government information in the United States. The site allows users to search thousands of government documents to analyze anything from campaign contributions to legislation and earmarks in order to detect abuse. The Sunlight Foundation's database has helped uncover several public officials that have used their political power inappropriately.[38] Similarly, OMB Watch, a government watchdog group, has created FedSpending.org that has tracked $16.8 trillion in U.S. federal government expenditures.[39] Likewise, to enhance public oversight of government programs, the Environmental Working Group has created an interactive website to show exactly where and to whom farm subsidies are being paid.[40] Outside of the United States, websites such as WikiLeaks.org provide whistleblowers an untraceable forum for anonymously posting documents that expose unethical behavior or oppressive regimes. The website primarily focuses on Asia, the former Soviet bloc, Sub-Saharan Africa and the Middle East, and as of 2008, the website had collected over 1.2 million documents.[41]

IT is enabling governments to benchmark the quality and effectiveness of their services. In Baltimore, the CitiStat program, mentioned earlier, looks at data in order to identify strengths and weaknesses in government programs. The city collects and puts in an easily understandable form a wide range of data on topics including the amount of overtime worked by employees, the frequency and type of citizen complaints, and response-time to specific cases.[42] One of the keys of CitiStat is its emphasis on the accountability of managers. The CitiStat system can be used to hold mid-level managers accountable, who in turn have tools to hold front line workers more accountable. Such systems can also make government more transparent, increasing pressures from citizens for even better performance. On a broader scale, the National Neighborhood Indicators Partnership (NNIP) at the Urban Institute partners with city governments around the United States to develop neighborhood information systems to monitor the state of their communities.[43] NNIP assembles data from multiple partners to allow local leaders to compare the effectiveness of different strategies for policy challenges such as welfare reform and prisoner reentry.[44] The Boston Indicators Project (BIP), another local initiative, is a collaborative effort of academics, civic leaders and residents to define, measure, and track progress on a variety of civic goals in the Boston metropolitan area. BIP aggregates data from multiple sources and makes the data and analysis of the data freely available on its website. BIP covers indicators from 10 different sectors ranging from traditional demographic trends such as home ownership and crime to environmental measurements such as green space distribution (acres per 1,000 children) to trust between neighbors. All of these different projects help democratize access to information and foster informed civic discourse.[45]

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15. Communities

Information technology (IT) has become so pervasive that its effects on society can be seen in the interactions between citizens and their communities. Strong communities have strong bonds between its members and with other communities, and IT is helping to link people and communities together all across the world.

As discussed below, IT has shepherded in a new era of online communities that supplement those found in the physical world. The interactions afforded by IT make it possible for the residents of smaller and remote communities to have access to products, services, and cultural opportunities that previously were available only in large cities. In addition, IT has introduced new media that are shaping personal relationships in the real and virtual worlds. Finally, IT is enhancing existing communities and fostering civic activity. Even businesses have found that IT has allowed them to be better corporate citizens and take on more corporate social responsibility.

Expanding Choices and Opportunities for Communities

Writing in the early 1960s, noted urbanist Jane Jacobs stated, "The point of cities is multiplicity of choice." And indeed, if one wanted choice—whether choice in occupations or choice in consumption—cities were the place to be. In contrast, while living in rural areas meant gaining certain things—such as a slower pace of life, more intimate community life, or access to nature—it also meant giving up certain things, particularly a broad choice of work and consumption.

If you wanted the most career choices, the most choices in entertainment, and the most choices in products and services, you had to be located in a city—the bigger, the better. Cities provided more choices because so many people lived there that it was economical for an organization to provide things that only a small percentage of people might want. Indeed, one of the advantages of living in a place like New York City was that because the city was so big, specialty stores of every imaginable type could find enough customers to thrive. In New York and other big cities, a small percentage of the population was a lot of potential customers.

But now, even a moderate percentage of customers in New York City pales in comparison to a small percentage of potential customers in the United States or indeed the world. The digital revolution is now reducing the link between choice and location. The biggest bookstore in New York or Los Angeles provides only a fraction of the books available at an online site like Amazon.com. Yet Amazon's choice of books is just as available to someone in a rural community of 1,000 people as it is to someone living in Manhattan, provided that the residents have access to broadband technology.[1]

But the choice in products available online is not just confined to books; it now extends to virtually any product distributed on the Web from music to videos. Posters.com, for example, stocks over 300,000 different posters. Ties.com stocks over 2,500 different ties. The online DVD rental site Netflix stocks 100,000 different DVD titles, whereas a typical neighborhood video store stocks around 3,000. Approximately 40 percent of sales at online music service Rhapsody are songs that are not available in music stores.[2]

Even the services once thought to be nontraded, or impossible to export beyond the immediate market, such as medical services or a college education, are increasingly provided through IT so as to reach remote areas. Many schools have created online courses, while others, like Massachusetts Institute of Technology, have posted course materials online. In addition, telemedicine, as discussed elsewhere in this report, can give rural patients the same access to care as the patient living in a major metropolitan area. Access to some things—like great museums or great restaurants—is still limited to people who live near or visit big cities, although collections owned by organizations such as the Library of Congress or the British Museum are becoming easily viewable online for research and educational purposes, thus bringing the experiences of such top-notch urban museums to the Web.[3]

In addition to helping residents of smaller and more remote communities have more choice in products and services, IT can also help their economies grow. IT can do this by making it more attractive for communities to attract new businesses or help new and existing firms thrive and access markets. Indeed, just as the Internet and broadband reduce the "dis-

Online DVD rental site Netflix stocks 100,000 different DVD titles, whereas a typical neighborhood video store stocks around 3,000.

tance" between rural and remote places to other resources, they also reduce the distance between businesses and their customers, making it easier for some businesses to thrive in rural or more remote areas. Various budding entrepreneurs attribute the Internet to helping their small businesses flourish. Becky Collins, known as "Granny B," is running a successful business of homemade pillowcase dresses from her rural hometown in Louisiana. With the help of her now independent website, Collins is now a full-time entrepreneur, demonstrating the potential of commerce with the help of broadband.

The scholarly literature on the role of IT and broadband telecommunications, in particular, on local economic development is limited, but some studies have focused on broadband and found that the presence of broadband does help communities grow. Lehr and colleagues found that communities in which mass-market broadband was available by December 1999 experienced more rapid growth in employment, the number of businesses overall, and businesses in IT-intensive sector between 1998 and 2002.[4] Likewise, Burton and Hicks found that in the central Appalachian region firms located in a broadband accessible zipcode had productivity rates between 14 percent and 17 percent higher than those of similar firms located in areas without broadband access.[5] In a study of counties in Florida, Ford and Koutsky found that Lake County, a community that had an early lead in fiber-optic broadband, experienced approximately double the rate of economic growth of similar counties without a fiber-optic broadband network.[6]

Strengthening Personal Relationships

From online social networks to online dating, IT has reshaped and revitalized the most intimate aspect of humanity: personal relationships. The stereotype of the typical computer user as a socially awkward introvert has long been disproved as IT has engaged every segment of society. In fact, rather than limiting social interaction, IT has created a tidal wave of new media for communication that has strengthened relationships both in the real world and the virtual one. The result has been twofold: allowing individuals to connect with a broader range of society and allowing individuals to use IT to maintain and strengthen their bonds to a larger social network.

The worldwide reach of the Internet has created a new global community and culture that spans traditional political and geographic boundaries. Users can congregate on websites targeted at specific communities to connect with other individuals who share their interests. From mainstream topics, such as sports or religion, to uncommon interests, such as the history of billiards, the diversity of the Internet helps bring people together. The result is that IT enables individuals to find others with whom they can develop relationships, even those who otherwise feel isolated or ostracized.

The Internet also helps bring people together by creating new ways for individuals to find each other. Websites such as Facebook.com and Classmates.com help reconnect old friends. Parents join websites to find others in their neighborhood who can share their experience with local doctors, schools, and job issues. Homeowners' associations can use services from LifeAt.com to create an online social network website for individuals living in their residential community. Using the LifeAt.com website, for example, neighbors can meet, organize activities, showcase the community to potential buyers and rate neighborhood businesses. In addition, websites such as Craigslist.com—the Internet's largest listing of local classified ads, job postings, personal ads, events and other announcements—provide custom portals for cities around the world that help residents find anything from a dog to a date. Many websites blend social networking features with another purpose. The websites Yelp.com and InsiderPages.com, for example, allow Internet users to rate local businesses and find others who share their opinion. The investments that people make in these online interactions yield positive benefits by creating a more connected and aware community.

Many individuals have turned to the Internet to form support groups. The Internet offers a number of benefits over traditional face-to-face support groups. Some people prefer the option of anonymity that the Internet affords users. Rape survivors who may feel uncomfortable speaking face-to-face with another person, for example, may open up to a counselor online. In April 2008, the Rape, Abuse, and Incest National Network launched an anonymous chat service for assault survivors to chat with trained counselors and in two months assisted more than 10,000 people.[7] Some individuals may find Internet support groups more convenient, either because no similar group exists near them or because they cannot attend traditional in-person meetings. Patients or family members of patients with rare diseases can join an online support network to find other individuals sharing their same experience. Others have found solace in documenting their experiences online and have used blogging as a vehicle for connecting with other people in similar situations.[8]

The anonymity of the Internet encourages users to engage with others and allows them to shed many social constructs, including race, class, and gender that inhibit face-to-face interactions. In place of such constructs, the Internet creates a meritocracy where individuals can be judged based on their contributions and character. For example, anybody from high school students to tenured professors can contribute to the collaborative online encyclopedia Wikipedia; however, the community will ultimately only accept the best ideas and writing. Even non-Internet transactions can use IT to help eliminate certain social stigmas. Some U.S. public schools have adopted a debit system using debit cards, personal identification numbers (PINs), or biometric fingerprint readers for the school cafeteria so that children who receive free or low-cost meals pay in the same manner as other kids.[9] For food stamp recipients in the United States, electronic benefit transfer cards that replace a paper-based system can significantly reduce the stigma associated with handling food stamps.[10]

Similarly, multiuser online games that attract thousands of users, such as the popular role-playing game "World of Warcraft," encourage real-time social interaction and teamwork between diverse sets of players that includes teenagers, working professionals, homemakers, and retirees. Although not all online relationships are created equal (as an executive at MySpace recently discovered after adding a virtual potato to his online friend list[11]), for many players the emotional impact of these online activities is real. A survey of multiuser online game players found that more than one-quarter of them agreed with the statement that their "most positive experience of the past seven days occurred in the game."[12] The impact of these games also extends into the offline world, as illustrated by the fact that the same survey reported that 16 percent of male players and 5 percent of female players had physically dated someone they met through the game.[13]

In fact, online dating itself is a growing phenomenon. In the United States, over 16 million people (or 11 percent of Internet using adults) have visited an online dating website.[14] Websites such as Match.com or Yahoo! Personals allow millions of Internet users to search through profiles of other users looking to date. Many specialized dating services have also cropped up that target an interest such as politics, the environment or sports, or a specific demographic, such as JDate for Jewish singles or Planet Earth Singles for ecofriendly daters. Online dating websites allow users to search for the person who best fits their criteria to find the perfect mate rather than waiting for a chance encounter, and many singles use these websites for their efficiency. For people who value chance over choice, IT applications for mobile phones such as Serendipity and BlueDating can help give fate a nudge: When two users running such applications on their Bluetooth-enabled mobile phones come into physical proximity, both users are alerted by the application if their personal profiles indicate a strong match.[15]

IT not only helps individuals find new people with whom to build relationships but also provides the tools with which many individuals maintain and strengthen their relationships both online and offline. The pervasiveness of IT has created a world of instant communication that has eliminated barriers to relationships such as distance. Technologies such as cell phones, instant messaging, and e-mail have enabled a new era of long-distance relationships for families and friends by helping people stay connected. From grandparents who can watch their grandchildren take their first steps on a webcam to spouses who use e-mail to stay connected while traveling, IT provides the crucial link between many people. These links help build stronger families: road warriors can easily call home to remain active members of their families while away from home.

Perhaps IT's greatest impact is on technologies used by people who are most in need of human comfort. Hospitalized patients read e-mail from friends and family to lift their spirits and encourage their recovery.[16] Soldiers away from home receive greeting cards embedded with microchips that their children can use to record a personal audio greeting. Even astronauts in space use e-mail and streaming media to stay connected with family and friends on Earth.

Tools to better manage the growing number of relationships of Internet users are also made possible by IT. Social networking websites such as Facebook.com and MySpace.com allow users to share personal information about their lives, develop new relationships with others and stay current on the activities of their friends. Other networking tools such as the LinkedIn.com website give users the opportunity to network online and expand their professional network using their existing connections. Social networking tools can have a substantial impact on users. Researchers have found that individuals use social networking, e-mail, and other forms of IT-based communication to build, maintain and enhance relationships and grow their social capital. Individuals then use this social capital when they need assistance such as finding a job or getting financial advice.[17]

An additional community benefit of the use of IT-enabled social networking tools is the expanded availability of social (or peer-to-peer) lending. Social lending allows individuals to go outside of traditional lending institutions and borrow money from family, friends, or simply other members of their community. Online services such as Virgin Money allow borrowers and lenders to easily establish rates, terms, and documentation for personal, business or real estate loans. Often borrowers can negotiate better rates and terms than they would get from a traditional lending institution, and lenders can receive better interest rates. In addition, family members can provide more generous loan terms and adjust the loan schedule or forgive payments if necessary. Another online lending service, Prosper, goes a step further and creates a marketplace where lenders essentially bid on loans requested by borrowers; rather than just listing a borrower's credit score and loan terms, this site allows potential lenders to view a borrower's personal statement, endorsements from friends, and group affiliations. In addition, each loan can be serviced by multiple lenders, so lenders can diversify their risk.[18] A similar online lending service, Zopa, which operates in the United Kingdom, Italy, Japan, and the United States, offers unsecured personal loans to borrowers with good credit. Unlike Prosper, Zopa underwrites all of its loans and investors' funds are guaranteed and insured by a partner credit union. Investors choose which borrowers to help and can increase their assistance by choosing a lower interest rate.[19]

Some scholars question whether IT, especially the Internet, only facilitates more bonding between like-minded individuals and does little to build bridges between diverse groups.[20] This remains an open question. There is no doubt, though, that by using the Internet, communities can share information about themselves with outsiders and help break down stereotypes and foster intercommunity dialogue. A YouTube channel launched by Queen Rania of Jordan in 2008, for example, has the express purpose of challenging Western stereotypes about Arabs and Muslims and building bridges between the different communities.[21]

IT-enabled social lending allows individuals to go outside of traditional lending institutions and borrow money from family, friends, or simply other members of their community.

Fostering Social Ties and Civic Engagement

Even though specific values and goals may vary by community, a key ingredient of a healthy democracy is a vibrant civil society. Achieving this requires an active citizenry with the values, skills, and knowledge to better their communities. IT can help by providing the tools to increase civic participation, improve community awareness, and organize individuals for collective action.

Many of the effects of IT on local communities and the social ties of their residents can be seen in

"Netville," the pseudonym for a residential suburban community outside Toronto of single-family homes supplied with free, high-speed Internet service as part of its design. Despite assurances at the time they purchased their homes that they would be connected to the local broadband network, about 40 percent of households were never connected. Thus, researchers were able to observe and compare homes with and without access to the broadband network. A team of researchers found that the residents who were wired to the broadband network—and therefore had access to a variety of services, including a videophone, online music, online health services, discussion forums, entertainment applications, and educational applications[22]—had a larger social network than residents who were not connected to the network.[23] The wired residents also participated more in collective action to solve problems, using online tools, such as a neighborhood e-mail list, to raise awareness of local events, coordinate social activities between residents, and organize residents for collective action (e.g., organizing against the developer to fix certain housing concerns).[24]

One way that IT encourages more active civic participation is by providing new forums for the public to find political information and engage in politics. As an example, the Internet provides voters multiple sources of information and opinions on candidates, party platforms, and policy proposals. Multiple studies have looked at the impact of IT on political participation in the United States. They have found that after controlling for a variety of factors (including socioeconomic status, partisanship, and traditional media use), voter turnout increases with access to the Internet.[25] In addition to mobilizing voters, other indicators of political participation also show a positive correlation with Internet access. The probability that an individual will donate to a political campaign, for example, rises with an individual's greater access to the Internet.[26] In fact, according to a recent Pew study on the effects of the Internet on the 2008 U.S. presidential election through June 2008, 46 percent of Americans used a form of digital communication as part of the campaign, both to acquire and send information about the candidates. Moreover, 6 percent of voters, up from 2 percent in 2004, used the Internet to make political campaign donations.[27] Similarly individuals who communicate over the Internet are more likely to be politically active by engaging in activities such as lobbying elected officials, signing petitions, or demonstrating in a rally.[28]

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Online political participation differs in many ways from offline political participation, often in ways that benefit the community. One important outcome of using the Internet for political participation, for example, is that factors such as socioeconomic status and age matter less when engaging in politics online.[29] Providing an alternative to face-to-face interactions causes many social barriers to disappear. As a result, socially marginalized groups are more likely to participate in community politics online, creating a more diverse civil society.

Membership in an organization is an important component of a health civil society, for it shapes an individual's identity, allows for the flow and exchange of ideas, and unites individuals to work together for a common cause.[30] Civic organizations can use IT to reduce organizational costs, make communication more effective, and organize civic action more efficiently. Thus, for example, large groups can operate more efficiently and with fewer barriers because of IT. Technologies such as e-mail and the Internet can allow organizations to greatly expand their membership and operations with little additional cost.

IT also helps address some of the barriers that arise from the dynamics within large groups. Economists such as Mancur Olson have theorized that rational and self-interested individuals will not take collective action to achieve an objective even when the entire group will be better off if the objective were achieved. The problem, Olson found, is that unless the benefits of group action occur only to active participants in the group, individuals will tend to become free riders.[31] IT helps reduce this problem by increasing transparency within an organization, making it easier to share information only to active members, and improving social ties and thus increasing social pressure to participate. Members are more likely to donate to an organization, for example, if they can track an organization's accomplishments online and receive members-only benefits such as access to a website or online newsletter.[32]

Organizations both large and small can use IT to facilitate communication with their members. IT encourages peer-to-peer communication on both a large and small scale. This phenomenon can be seen in the American political system, with centralized organizations such as MoveOn.org influencing a large segment of the political left and decentralized websites such as DailyKos.com fostering a community-based political dialogue.[33] Similar websites such as RedState.com and Townhall.com appeal to those on the right in American politics. In addition, websites such as Meetup.com encourage an active civic life by connecting individuals with others who share their common interests. Over 2 million people around the world have used the service to find local groups ranging from political organizations to foreign language clubs.[34]

Many organizations also rely heavily on the Internet for online fundraising. Since Howard Dean first demonstrated the fundraising potential of the Internet in the U.S. presidential primaries of 2004, both major and minor political candidates have used the Internet to raise millions of dollars. Many tools are available online to help individuals raise funds for their charitable cause. The website Active.com hosts a variety of tools to organize and fundraise for a charity sporting event. Marathon runners, for example, can form teams, recruit additional members, solicit and track donations, and finally receive and publish their fundraising and athletic results.

The Internet has also given rise to micro-philanthropy where citizens can directly fund specific projects or people. As an example, DonorsChoose.org allows teachers in public schools in the United States to solicit help from online donors to fund a specific classroom need. Requests may be small, such as buying new pencils for the classroom, or large, such as funding a class fieldtrip. Since first launching as a small pilot project in North Carolina in 2000, DonorsChoose.org has provided public schools more than $20 million in support. By using IT, donors of all contribution levels can be given access to the same advanced tools including project information, accountability reports, and a personal giving report. These tools allow donors to see the impact of their contributions and encourage more charitable giving.[35]

Organizations also use IT to recruit, manage, and train their volunteer staff. Websites such as Idealist.org connect nonprofit organizations around the world with volunteers, job applicants, and interns. Organizations can also use their own websites to advertise volunteer opportunities and develop online training materials for new volunteer staff. In addition, organizations use software to track volunteer contact information, skill sets, and performance. Web services such as WhenToHelp.com, available for free to nonprofit organizations, automate volunteer scheduling and let volunteers specify their availability and trade shifts online. A similar product, Count Me In, automates registration and league management for youth sports leagues. Websites such as DinosaurExchange.com helps active retirees find opportunities to put their professional experience to use as a consultant or mentor. These types of tools help make civil society more efficient and allow citizens to more actively participate in their community.

Moreover, many of these websites not only provide online tools to promote civic action but also develop their own online community. Idealist.org, for example, has many social networking components to build relationships between its users. Users can build online profiles, engage in online discussions, participate on blogs, or listen to podcasts. Similarly, Active.com provides community message boards, blogs, and individual and team profiles where members can share training plans, seek and give advice, and share their stories or success. In addition to improving real-world communities, these websites are building new virtual communities of their own.

IT also helps increase community awareness. Community blogs provide first-hand insights into local issues and politics and act as a knowledge base for other community members. The current Foreign Minister of Sweden Carl Bildt, for example, writes a blog that educates the populace about relevant Swedish and European Union undertakings.[36] Every citizen can have a voice, and the Internet creates a platform where often the best ideas, rather than the best-funded ideas, can win over the most people.

In addition, blogging has brought out new voices in communities. One survey found that more than half of all bloggers in the United States have never published their writing anywhere else.[37] Traditional media, such as community newspapers or newsletters, face limits on their publication frequency and depth of coverage because of the cost. In contrast, operating a small blog requires little capital and can easily scale to meet the needs of a community. In addition, blogs provide more interaction between community members through features such as commenting, social bookmarking, and links to related blogs.[38] Even larger undertakings can serve a vital community need. In Los Angeles, for example, the major newspapers only covered about 10 percent of the homicides in the county. Many of the homicides that went unpublished occurred in the African-American and Latino communities. To help put a human face on the deadly statistics and document the toll of the homicides on the community, one journalist began "The Homicide Report" a blog that tracks and details every homicide in the county.[39] As a result, residents have a greater awareness of homicide and its impact on their community.

Promoting Corporate Social Responsibility

Although IT has long been hailed as a tool for companies to lower costs and raise productivity, IT is also being used to increase transparency and encourage companies to be better corporate citizens. Companies recognizing their corporate social responsibilities are contributing to local communities, maintaining ethical workplace standards, and engaging in environmentally friendly practices.

With the growth of international supply chains' buyers and retailers are constantly at risk of being associated with companies across the globe whose ethical workplace standards do not live up to the reputations retailers are working to protect. To complicate the problem, the escalation of foreign-owned companies in the developing world has created the potential for arms-length industrial relationships as managers and floor-level employees come from different cultures and at times, speak different languages. IT is helping to bridge the information gap between managers, workers, and buyers further down the supply chain by enabling organizations to emerge as one-stop-shops for monitoring and mediating between diverse global interests. Clear Voice Hotline (CVH) works in Latin America to give employees access to legal rights and free advice through their hotline and website.[40] In addition, by employing indigenous operators and consultants, CVH is able to train companies on how to best interact with their employees. CVH then aggregates their complaints and produces company reports that are available to buyers and shareholders who are interested in social compliance.[41]

In addition, IT solutions can help companies track and manage the risk of a supplier breaching their corporate ethics standards. By using an IT system, companies can more easily collect and share information about compliance with standards regarding child labor or the disposal of environmental waste among their various business units and external stakeholders. In addition, companies can use IT to analyze this data to spot early warning signs of noncompliance and create an automated virtual auditing system based on pre-defined business rules and policies. An IT-enabled system can rank and prioritize suppliers for intervention, either through direct audits or face-to-face education and training, on the basis of their computed risk levels.[42]

Many companies are using IT to become better corporate citizens on their own. Marks & Spencer (M&S), a leading U.K. retailer, is an example. Behind its ambitious Plan A, a £200M "eco-plan" to make its operation environmentally friendly, M&S has used IT to coordinate its global supply chain that consists of 2,000 suppliers and 20,000 farmers. The company has created a best practices website called Suppliers Exchange, that allows traditionally different parts of the business model to interact. Thus, for example, farmers who create biogases from farm waste are now selling energy to M&S, along with their beef. But without an accountable Web-based information exchange the program would not work. "If you don't know who you are buying from, you can't manage the issues," said Mike Barry, who heads the M&S corporate social responsibility department.[43]

Corporate social responsibility is becoming more imperative at a time when IT, especially the Internet, has increased public access to information about firms' conduct. Activists can easily organize online to protest and boycott companies that engage in questionable behavior. Thus, for example, the digitization of financial information on publicly traded companies has allowed the Sudan Divestment Task Force to monitor companies with questionable ties to the Sudanese government and then lobby public pension and other funds to divest from these companies.[44] Even the Chinese government, typically seen as impervious to public opinion or corporate responsibility, was stopped by local protestors when it tried to build a petrochemical plant in Xiamen and Chengdu. The protesters were able to organize themselves quickly using blogs and short-message service (SMS) technology.[45]

Moreover, the Internet has changed the way consumers create and share preferences on corporate behavior. By giving voice to anyone willing to go online, blogs have become an essential element of how information on firms is communicated. The power of blogs is amplified by search engines like Google that rank search results by the number of links to a given page. Now a single online search can determine more about how a company is perceived than a multimillion-dollar ad campaign.

In addition, companies have used the Internet to build interactive websites to collect user feedback on its products and services. Dell, for example, launched its IdeaStorm website in 2007 to more easily solicit ideas and suggestions from its customers that could be integrated into the product development lifecycle. Using this website as a virtual suggestion box, online users can submit their feedback and vote for the best ideas. In turn, Dell tracks which ideas are submitted, reviewed and implemented and provides more transparency to its customers on its initiatives and business decisions. Many of the ideas submitted to the IdeaStorm website go beyond suggestions to Dell on how to build better technology and instead focus on issues such as strategies for becoming more socially responsible. Suggestions submitted through the IdeaStorm website helped lead, for example, to Dell's decision to become carbon neutral and to its decision to become a partner in the RED™ initiative, under which a portion of profits from each RED-branded products sold goes to the Global Fund, a nongovernmental organization fighting AIDS in Africa.[46]

The Web also has enabled the growth of over 100,000 new organizations focused on social issues.[47] For example, a survey of over 250 global business leaders found that three-quarters of them reported that the number of organizations asking for information about their operations has increased over the past three years. The same percentage of businesses report having increased the amount of information they make available regarding the environmental and social impacts of their business practices.[48] As the Internet becomes more of a tool for watchdog groups to scrutinize the behavior of firms, companies are going to greater lengths to prove, in depth, their socially responsible qualifications. Starbucks, for example, has an entire section of its website promoting its partnership with organizations like Save the Children and the American Wildlife Foundation and it has published on its site a corporate social responsibility report annually since 2001.[49] The Gap also touts its corporate social responsibility credentials on its website and has undergone an aggressive campaign to showcase its involvement with the RED campaign.

Since "hiding" bad behavior is much more difficult in the information age, a growing share of corporations are using transparency to build trust in the eyes of stakeholders and to develop a better dialogue with nongovernmental organizations that monitor

The Chinese government was stopped by protestors when it tried to build a petrochemical plant in Xiamen and Chengdu after protesters quickly organized using blogs and SMS technology.

activities such as unfair labor practices or environmental standards.[50] One of them, Vodafone, which was ranked as the number one socially responsible company in 2006 by *Fortune*, has a "CR Dialog" page on its corporate social responsibility webpage that links conversations between experts, stockholders, and other interested parties about what actions the cell phone industry can take to become more socially responsible. Vodafone also has a section highlighting third-party audits of the company's behavior.[51] BP, ranked the number two socially responsible company, has on its website a list of socially relevant topics such as human rights, natural disasters, and HIV with links to in-depth policy reports, case studies, performance reviews, and future program plans, along with feedback options so users feel like they can interact with the company.[52]

Corporate social responsibility is moving beyond a marketing campaign to an authentic effort reflected in firms' business models. The accessibility of corporate information is creating a "race to the top" over which companies can perform the best. Although corporate social responsibility in the past was seen as a necessary cost for corporations, a recent report by IBM showed that two-thirds of the business leaders surveyed used corporate social responsibility as an opportunity for financial gain.[53] *Fortune* reported in 2006 that $1 out of every $10 of assets under management was being invested in firms with high ranks on corporate social responsibility scales.[54]

IT not only is helping to create transparency that reduces harmful business practices but is also allowing corporations to reap the goodwill generated from their good deeds. This goodwill, in turn, creates a stronger partnership between customers and the companies, as well as better avenues for the companies' growth.

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16. Developing Countries

Information technology (IT) has the potential to revolutionize the lives of people in developing countries. Many of the ways that IT can improve lives in developing countries mirror the ways in which it improves lives in the developed world. But the developing world faces several unique challenges—including widespread poverty, hunger, and health crises in both urban and rural communities.

IT alone cannot solve all of the problems facing developing countries, but IT should be part of the solution. With IT, individuals in the developing world can see and share valuable information. Farmers can get up-to-date weather forecasts and information about the latest fertilizers and farming techniques. Patients in remote villages can see specialists online rather than traveling for hours to the nearest clinic. Schoolteachers can download educational materials and lesson plans for their students. Philanthropists can give a small loan to someone thousands of miles away with the click of a button.

Creating economic, social, and political parity between the developed and developing world will requires more than flash-in-the-pan solutions such as a few Internet kiosks in rural India. Real development will require policies and technical changes that lead to long-term growth and sustainability in developing countries. Fortunately, IT is helping to facilitate such policies and changes. In the educational realm, for example, IT is enabling remote education, overcoming distances that are barriers to development. In the economic realm, IT is bringing cell phones to rural areas of India that enable farmers to get marketplace information in real-time, and IT is also creating sustainable, fluid markets that will allow people to save, invest, and grow—the very same way IT has helped the economies in developed countries. The many ways in which IT is reshaping developing countries—creating better markets and economic opportunities, expanding access to capital, making government more transparent, increasing access to educational opportunities, and improving health care—are discussed further below.

Creating Better Markets and Economic Opportunities

Studies have found that local economies with more access to IT are more productive than those with less access.[1] This finding certainly holds true for local economies in the developing world, where IT is helping to reduce poverty by creating better markets and increasing economic opportunities. People in developing countries can use IT to get access to market information that enables them to gain better terms of trade with wholesalers and other intermediaries and to make better decisions about what and when to produce.

In 2001, for example, the villages and local governments of the Dhar district in central India, with financing from the Indian State Finance Commission, joined together to fund the Gyandoot project to build a low-cost rural Intranet joining 20 village information kiosks.[2] This project enabled villagers in the district to share information and access the Internet using dial-up connectivity through local exchanges on optical fiber or ultra high-frequency radio links.[3] Farmers using this service went online and found a distant village that was will to pay more for their potatoes than the local rate. As a result, the Gyandoot project has increased prices paid to village farmers by 3 percent to 5 percent and saved the farmers from having to pay commissions to middlemen.[4] Similarly, Tradenet.biz is a wireless-based website that people in Ghana and other West African countries can use to trade agricultural products using short message service (SMS) communications.[5]

The Indian Tea Board, the body responsible for the world's largest tea market, has created a similar initiative to use IT to facilitate tea spot trading. Tea has been traded in India since 1861 at the Tea Auction Center in Assam, where transactions have been brokered in person and recorded on paper. In 2008, the tea markets are going digital. The move to computerized tea auctions will allow buyers to bid from anywhere in the world. Studies in other commodity markets have shown even modest reductions in transaction costs through automation can produce large increases in trading volume. The hope is that computerized spot trading will result in more efficient services and fairer prices for India's tea farmers.[6]

Small and medium-sized enterprises (SMEs) are the bedrock of all economies, developing and developed.[7] By reducing the costs of doing business and increasing the ease and spread of global sup-

A World Bank survey of over 20,000 businesses in low- and middle-income countries found that firms that use IT have faster sales and employment growth and also higher productivity.

ply chains, IT is significantly reducing the value of economies of scale and increasing the capacity for growth among SMEs in the developing world. These new SMEs, in turn, are using IT to do business at a far greater rate than their traditional counterparts. In India, for example, 1 million of the country's 7 million SMEs are ready to incorporate IT in their business, creating a market worth $459 million annually.[8] SMEs that use IT are more likely to produce innovative products and services that affect national progress as a whole, creating development that is less dependent on short-term aid and more associated with long-term economic prosperity.[9] A 2005 World Bank survey of over 20,000 businesses in about 50 low- and middle-income countries found that firms that use IT have faster sales and employment growth and also higher productivity.[10]

Mobile communications can restructure businesses in developing countries by economizing services, enabling businesses to make "just in time" transactions and deliveries.[11] A 2005 London Business School study found that mobile communications has a significant positive effect on a nation's economy: For every additional 10 mobile phones per 100 people, a nation's gross domestic product rises .5 percent.[12] Another study found that poor Chinese villages that gained telecommunications access had 15 percent higher income growth than villages that did not gain access.[13] Although much of the recent literature emphasizes how mobile phones help producers, consumers benefit from cell phones as well. One study by an economist at Brown University, found, for example, that new phones positively impacted the fish industry in southern India by increasing profits for sellers by 8 percent and bringing down consumer costs by 4 percent.[14]

To help increase access to mobile technology, organizations such as the Grameen Foundation provide microloans to people who want to establish standalone mobile phone operation. Such loans allow people to buy a Village Phone Kit, which includes a mobile phone, an antenna to pick up signals, and a battery or solar panel for recharging.[15] Since 1996, the Grameen Foundation has financed more than 250,000 "phone ladies" in Bangladesh, Uganda, and Rwanda.

Making markets more efficient is important, but developing countries have little chance to advance economically if consumers in the developing world cannot save and accumulate capital.[16] A major cause of financial insecurity in the developing world stems from price volatility. When markets are broken because of geography and poor communication, prices become localized; the localization of prices, in turn, creates significant price volatility. The problem of price volatility is amplified by the fact that people in the developing world have very meager resources. When the price of grain fluctuates considerably, it is particularly hard for an impoverished family in Nigeria or elsewhere who may be living off less than $10 a day to plan for its financial future.

IT allows farmers in developing countries to know for the first time what their goods are worth countrywide so that they can try to sell their goods where they will be most profitable. By creating this information exchange, IT helps to stabilize food prices and to allow the market to dictate where food should be directed. In Niger, for example, cell phones were phased into the economy between 2001 and 2006 in order to help farmers and other market actors get a better picture of national grain prices. A study by the University of California found the program reduced annual price volatility by 10 percent.[17] By providing a better picture of the market, cell phones can also limit the human cost of food shortages. During Niger's 2005 food crisis, prices were 20 percent higher in famine areas than in areas where food was plentiful.[18] If this information was readily available to farmers there would have been a stronger incentive to get food to the areas with the most suffering, significantly reducing the loss of life.

Just as in developed countries, in developing countries IT also increases productivity. In India, for example, the National Dairy Development Board (NDDB) has implemented a program to promote the use of IT to increase milk production. In 2000, the NDDB automated the milk-buying process at 2,500 rural milk collection societies by installing dairy information services kiosks (DISK) that enable farmers to immediately receive payments for their milk (rather than waiting 10 days under the previous system) and manage a database of all dairy cattle in India.[19] The DISK system consists of kiosks where farmers can weigh their milk, analyze it for fat content, and receive a payment using a plastic identification card.[20] Farmers also use the kiosks to access a complete history of all dairy cattle as well as data on milk production, and they can place orders for a variety of goods and services.[21] The DISK system has now been replicated in 70,000 villages in about 200 districts in India.

India is currently exploring ways to use IT to bridge the information gap between agriculture experts and local farmers. Farmers who are geographically isolated usually do not reap the highest possible crop yields because they do not get the most up-to-date advice on crop cultivation. India's Agricultural Information Dissemination System (agrIDS) is an IT-powered plan to disseminate agricultural information throughout India in order to increase yields and make every farmer an expert. Preliminary studies have predicted that access to real-time crop information will increase crop yields by 25 percent.[22] In a more rudimentary program, farmers in rural India have begun to use IT to subscribe to Reuters alerts to receive updates on weather and market prices via text messaging.[23]

Expanding Access to Capital

Many private companies in developing nations—such as financial institutions—do not have the capital or the incentives to establish services in remote areas. Information can bridge these gaps in two ways. First, IT can help people engage in transactions over long distances, such as sending or receiving money, even in the absence of local financial institutions. Second, IT enables microcredit organizations such as the Grameen Foundation (originally the Grameen Bank) and Kiva to bypass governments and provide loans directly to individuals. These innovative organizations can operate at lower cost than traditional loan programs, and, in the case of Kiva, they deliver 100 percent of the donation to the recipient, without deducting fees for their services (although people can opt to provide an additional 10 percent donation to defray costs).[24]

IT also enables people without access to banking services to exchange money. In particular, many people who live in remote areas in developing countries may have to travel hours to the nearest town to get to a bank. This lack of accessibility, coupled with extremely low incomes (perhaps less than a dollar a day), means that many people in developing countries may not have a bank account. Without the ability to save or transfer money, they must physically transfer payments to family members or to purchase goods or services from vendors outside their villages. Wireless communications bridge this gap by allowing people to send small payments via mobile phones. The World Resources Institute predicts that banking over mobile wireless communications will bring into the formal economy huge numbers of people who were previously excluded.[25]

In Kenya, for example, a partnership between Vodafone and Safaricom, Ltd., recently created a service called "M-Pesa" (which means, "mobile money") that allows people to send money using a network of mobile phones. The sender pays cash to an agent in one location, who then sends a code number via a text message to another agent located where the person who is receiving the cash lives; the second agent then makes the payment to the intended recipient.[26] This service has proven extremely popular, with 6,000 new subscribers signing up each day.[27] The M-Pesa program had hoped to add 200,000 customers in its first year, but that many customers signed up in just a single month.[28] A year later, the number of customers reached 1.6 million, and Vodafone is expanding the service to Tanzania and India.[29]

Privately funded foreign aid is a vital form of financial support for developing countries. For every $1 of aid from official institutions in developing countries, there is currently $2.61 of privately funded foreign aid. And in some developing countries, there is even more private aid. In the Philippines, for example, there is $25 of private aid for every $1 of foreign aid from official institutions; in India there is $31, and in Mexico, there is $150 of private aid for every $1 dollar of foreign aid from official institutions.[30]

Streamlining aid from individual donors in order to make sure it gets to people in need is challenging. IT is making it easier than ever to address that challenge. Kiva, for example, operates a person-to-person microlending website that allows individuals to make microloans to individuals in developing countries and then track how the loan recipient is using the money, helping donors decide whether or not to accept repayment of the loan (99 percent are repaid) or to reinvest it.[31] Kiva can deliver funds loaned by individuals much more quickly than traditional government or bank loan funding would be delivered. Thus, for example, the owner of a Ugandan store can post a request for financing to buy supplies and within hours receive a loan of $75.[32] Potential lenders can determine whether to make a loan based on the recipient's individual risk rating. Kiva further mitigates risk by disclosing scams immediately (as well as good news from entrepreneurs who received loans).[33] Kiva had facilitated more than $22 million in microloans in over 40 countries as of February 2008 and hoped to reach $100 million by 2010.[34]

A significant source of capital for the developing world comes from money sent from migrants back to their home country. Transfers of money from foreign workers to their home countries—called remittances—constitute the second largest financial inflow into developing countries, dwarfing international aid.[35] A recent study found that in 2006 global remittances totaled three times that of aid provided by donor nations to the developing world.[36] IT is helping to make expatriate aid more successful by connecting potential donors with those in need. The website Mukuru.com, for example, allows members of Zimbabwe's diasporas to buy goods such as food and gas over the Internet for family members back home. The site has 10,000 clients so far and intends on expanding to serve a half dozen more countries next year.[37] Traditionally, there have been high transaction costs for remittances due to diffuse and decentralized payment methods and the lack of information provided to migrant workers. Recognizing the potentially debilitating effect such costs could have on the developing world, the U.K. Department of International Development created a website called Send Money Home, which offers free advice about exchange rates, transfer rates, financial planning, and more. This website not only helps migrants get the best transaction price by allowing users to choice amongst a series of private providers but also assists migrants in making the best financial decisions for themselves and for the people to whom they are sending money.[38]

IT enables microcredit organizations to provide loans directly to individuals; as of February 2008, one organization had facilitated more than $22 million in microloans in over 40 countries.

Making Government More Transparent

Having a functioning, responsive government is a precursor to a nation's economic well-being, yet much of the developing world suffers from governments who are unresponsive to their citizens because of corruption. Although corruption affects governments in every country, the toll of corruption is particularly harsh in developing countries when resources are diverted from pressing social needs. Corruption not only disproportionately impacts poorer citizens but also makes businesses less competitive. One study has shown that corruption has increased the cost of doing business for SMEs in India by 20 percent.[39] In addition, many studies have found that corruption is inversely related to foreign direct investment.[40] IT helps make governments more transparent by giving leaders who want to be responsive to their citizens the tools to do so and by increasing accountability for leaders who do not act in their people's best interest.

Much of the corruption in the developing world is rooted in the inaccessibility of government resources. What is usually a free and open process in the developed world, such as filling out the necessary paperwork to start a business, can be impossible in developing countries without bribing government officials.[41] The easiest way IT is combating this problem is by "disintermediation" between services and citizens.[42] By automating procedures that would traditionally require interaction with a local bureaucrat, IT helps reduce the power asymmetries between officials and citizens, thereby reducing the likelihood of forced bribes and corruption. It is interesting to note that a recent World Bank survey of eight e-government projects across India found a decrease in corruption for each area once the government program became computerized—and in one of the areas, bribes were reduced from 30 percent of transactions to less than 1 percent.[43]

Far more detrimental to developing countries than bribery is what developmental economists call "the resource curse"—where countries rich in natural resources produce little long-term growth and have undemocratic governments because leaders derive wealth from selling their country's natural resources instead of growing a vibrant domestic economy or related tax base.[44] Once the country's resources run out or global markets reduce demand for those resources, such countries do not have any domestic markets or cash reserves to fall back on. Researchers have found that countries with unrepresentative governments and natural resources actually end up worse off than countries without domestic natural resources.[45] By bringing greater transparency to governments in the developing world, IT is beginning to be used to solve this problem.

The partnership created in 2007 between SAP AG, the largest business software company, and the Extractive Industries Transparency Initiative (EITI) illustrates how.[46] EITI was created by a group of governments, companies, civil society groups, and investors to link the sale of resources to economic growth and poverty reduction by requiring governments and companies to disclose statements of all financial transactions.[47] Partnering with EITI, SAP is using its IT resources to share data on participatory companies and countries, encouraging mutual accountability and transparency. Although the SAP-EITI partnership is relatively new, it is already showing impressive results. More than half of the 54 resource-rich countries in the world have committed to implementing EITI or are in the process of doing so—and Nigeria received a markup in its sovereign risk rating after implementing EITI, showing that investors believe the program will help stabilize the country.[48] Beyond cutting down on corruption, programs like EITI have the ability to create economic opportunity. According to James Farrar, SAP's vice president for corporate citizenship, "these countries are resource rich but capacity poor. If processes like EITI succeed, we will have huge markets there."[49]

In addition, IT is making governments in developing countries more accountable by providing the tools necessary to prove human rights violations. Amnesty International, for example, is working with the satellite-imaging firm AAAS to record violence in Darfur to prove Omar al-Bashir's government's involvement in the genocide. The group posts before and after pictures of villages that have been destroyed on its website Eyes on Darfur.[50] Similar satellite imagery and video recordings were posted online by Amnesty International in 2006 to show the devastating effects of the Zimbabwean government's policy of brutally evicting poor inhabitants from their shelters and then demolishing entire urban settlements.[51]

Another way that IT is increasing government accountability in the developing world is via the Internet. Blogs, e-mail, and search engines have allowed people all over the world to communicate and shine light on inappropriate action from unrepresentative governments. The recent protests over the repressive ruling junta in Burma were far less violent than in 1988, and one of the reasons suggested is that, unlike the 1988 protests, the more recent demonstrations were all over the Internet and people across the globe could watch how the military treated protestors.[52] In the information age, repressive governments are finding it harder and harder to hide behind national boundaries.[53]

In the Brazilian state of Amazonas, satellite technology is enabling 10,000 children to be educated in areas where a lack of serviceable roads often prevents them from going to school.

Increasing Educational Opportunities

IT is increasing educational opportunities in the developing world in several ways. One is by increasing educational opportunities for women. A disproportionate number of the people without access to primary education in the developing world are women. Women also make up two-thirds of the world's illiterate population.[54]

A prime example of the use of IT in educating women is the Internet radio production training offered by the nongovernmental organization in Brazil called CEMINA (Communication, Education, and Information on Gender in Portuguese). Several years ago, CEMINA created a women's radio network that promotes communication and education on gender and civil rights issues. Its women's radio program is aired throughout Brazil on over 400 radio programs. With the advent of digital technology, radio production has become much easier. In the past few years, CEMINA has formally trained over 1,500 women in Internet radio production at community telecenters in underserved communities. Integrating a familiar technology (the radio) with the Internet has made it easier to train women to use the new technology. CEMINA's Internet website called "Radio Fala Mulher" (Women Speak Up in Portuguese) allows users to ask questions, propose topics, and share material. The overwhelming success of this project has led CEMINA to expand its mission to include information on child labor.[55]

IT is also being used to help overcome the geographic isolation that has often made it impossible for students in remote rural areas to get access to a formal education, particularly if they must travel miles to get to the nearest school. In the Brazilian state of Amazonas, for example, satellite technology is enabling 10,000 school children to be educated in areas where a lack of serviceable roads often prevents them from going to school. Teachers present their classes at a state educational facility, and the classes are then broadcast in real time to the rural communities via a two-way satellite link.[57] During the broadcast, students can communicate with 260 onsite teachers.[58] The result is that students who otherwise might have little access to education can now "go" to school.

Some large companies in the private IT sector are helping to educate people living in the developing world, as well. Forward-thinking companies consider where the next big market will be. For companies in the IT sector, it is important that customers be comfortable with the technology they offer. For that reason, IT specialists and companies have begun training individuals and SMEs throughout the developing world in new technology.[59] As an example, Microsoft's Community Technology Skills Program partners with local organizations such as libraries or small businesses to offer donations, software, curriculum, and technical expertise. Thus far, Microsoft's program has created over 37,000 partnerships across more than 100 countries and regions.[60]

A U.S.-based not-for-profit organization called Geekcorps, similar to the Peace Corps, is dedicated to cultivating high-tech skills and businesses in the world. Geekcorps has been on the ground in West Africa and other regions for more than five years. In Ghana, for example, Geekcorps places a volunteer IT specialist from the developed world with SMEs to train their local employees. Although the Geekcorps program in Ghana has involved, on average, only 14 companies a year, that is a start—and the progress is nontrivial considering that Ghana is a country where nearly 50 percent of the population lives on less than $1 a day, and there were fewer than two telephones per 100 people in 2001.[61]

Improving Health Care

In addition to improving educational opportunities, IT is helping to improve health care in developing countries. In Uganda and Mozambique, for example, since 2003, the AED-Satellite Center for Health Information and Technology has distributed 600 personal digital assistants (PDAs) to health care workers, who use them to collect public health data, which they upload to a central server.[62] Health care professionals in these countries' capital cities analyze the data and send responses and other information back to the local health care workers, thereby helping to educate them and improve the services they provide.[63] Another example is the Karnataka Telemedicine Project. Launched by the Indian Space Research Organization launched in 2002, this project connects a special hospital for heart care in Bangalore, India, with hospitals in remote districts using very small aperture terminals (VSATs), which are most commonly used to transmit narrowband data.[64] The project thus enables medical specialists to provide diagnoses and treatments to patients via videoconferences.[65]

An equally compelling example of IT's use in improving health care is what cell phones are doing to reduce the infant mortality rate in Mali. In rural Africa, most cases of infant mortality are from diseases that are easily treated but are not detected. A new project called Pesinet provides cell phones to trained women in rural villages, who then transfer medical information on the village's infant population to trained medical professionals. The simple monitoring process can significantly improve infant health. When a similar program was run in Saint-Louis, Senegal, for example, the infant mortality rate dropped from 120 infant deaths per 1,000 births to eight deaths per 1,000 births. Beyond yielding the astonishing medical outcomes, the infant health project is surprising cheap, costing around $1 per child per month.[66]

Yet the right tools without the right technicians do little good for the world's poor. Sub-Saharan Africa is the sickest region on the planet, carrying 25 percent of the globe's disease burden, yet it has only 3 percent of the health workforce. Because of Africa's geography and poor infrastructure, training local health care providers has often been an insurmountable challenge. Yet IT and e-learning are creating cost-effective solutions by overcoming physical boundaries and the traditional economies of scale associated with developing a health care industry. In South Africa, for example, nurses dealing with skin diseases are given laptops and webcams and are remotely assisted by dermatologists from all over the world.[67]

Another way that IT is improving access to health care is through the availability of geographical information systems (GIS). A GIS is a combination of digitized maps, aerial images, and geographic data. Developing countries' health care officials can use GIS programs to determine where certain diseases are prevalent, which enables them to design effective systems to deliver health care to targeted areas.[68] In particular, good health care system management depends on local and national health care officials being able to make informed decisions regarding resource allocation.[69] Using GIS data, health care officials in developing countries can determine the prevalence of diseases and also health care coverage. This information helps them to decide how to allocate scarce health care resources. South African health care officials in the Hlabisa subdistrict, for example, used GIS to determine where health care coverage was lacking and were able to plan new clinics accordingly.[70]

One of the most disheartening health care challenges in the developing world is the number of deaths caused from curable diseases such as tuberculosis (TB). In many instances, despite the availability of medicine, TB patients still die because they do not take the medication as regimented. To tackle the problem, doctors in Cape Town came up with a simple but extremely effective idea—text message TB patients reminding them to take their medication. The medical team estimated 71 percent of their patients had access to cell phones and after the pilot study only one treatment failure was reported out of 138 patients. Currently, the South African government is working to expand the text-messaging reminder program nationwide to HIV patients.[71]

Looking Forward

IT should not be regarded as a silver bullet for development or a substitute for traditional development tools. IT will most effectively improve the lives of people living in the developing world by being used in conjunction with the adoption of sound government policies, the development of functioning markets, investments in infrastructure, and the education of a more advanced workforce.[72]

Many obstacles remain to be addressed before the full potential of IT can be realized in the developing world. One obstacle that is impeding the spread of IT in developing countries is language. Asia, for example, is the most populated region in the world—and a huge potential market for IT. Yet 80 percent of the people living in Asia cannot read English, making much of the world's Internet content inaccessible. Asia itself is one of the most culturally and linguistically diverse regions of the world, with more than 2,000 languages.[73] In order for IT to have its full impact in Asia and other parts of the developing world, more needs to be done to create Internet content in local languages. Making the content of the Internet in the local language of the users is called "localization." Localization requires not just changes in language, but also the definition of standards for such things as encoding, keyboard layout, sorting sequences, and local terminology.[74] Various types of applications in local languages are required, as well. Commercial incentives are not high enough in developing countries for software vendors to create the needed changes on their own. For that reason, intervention by governments and nonprofit organizations is needed. One partnership of universities, government agencies, and IT specialist in Asia working to create policies for localized language content and facilitate technical support for localization is the PAN Localisation Project. The project is currently working to localize content in Laos, Cambodia, Bangladesh, Nepal, Bhutan, and Sri Lanka.[75]

Another obstacle to IT use in the developing world is a lack of digital literacy among many countries' populations. Several reports have shown that people who are unfamiliar with technology have trouble on the Internet with "branching" (being able to navigate a nonlinear environment), synthesizing and reproducing retrieved data, and assessing the quality of the information.[76] Digital literacy in the developing world is also related to the lack of access to digital technology in developing countries. As access to the Internet and other forms of IT increase throughout the developing world, opportunities to learn how to use IT will increase as well. One approach to increasing digital literacy in the developing world is to use more familiar technologies to train new users—just as CEMINA used the radio to teach woman in Brazil how to use the Internet.

A third obstacle to IT use in developing countries is the lack of access to digital technology. The Internet has the potential to transform the lives of people in the developing world. Yet, although the number of Internet users in developing countries has steadily increased—from about one Internet user per 1,000 people in 1993 to 73 Internet users per 1,000 in 2003, significant gaps in access to the Internet remain.[77] More encouraging has been the mass increase in cell phone usage. In 2004, for example, sub-Saharan Africa had only 5–8 million Internet users but 52 million mobile phone users.[78] Expanding the development potential of IT further will require a mixture of broadening access to IT, as well as deepening the existing digital infrastructure into the wider social and economic fabric of the developing world.

Finally, cost is a roadblock to the use of IT in the developing world. To a large degree, people in developing countries cannot afford technology, such as a wireless handset or a personal computer. On the other hand, the declining cost of computing power is enabling manufacturers to build cheaper handsets and personal computers, bringing them for the first time within reach of some of the world's poorest citizens. This is the goal pursued by Nicolas P. Negroponte, who created the One Laptop Per Child Foundation (OLPC) to offer personal computers for as little as $100. Unfortunately, purchases of the OLPC laptop computers have fallen short of OLPC's goal of $1 million even though the governments of several developing countries, Haiti, Rwanda, Peru, and Uruguay, have ordered the laptops.[79] Nevertheless, a positive outcome of the OLPC program has been to spur other companies to compete to produce inexpensive laptops—Intel's "Classmate" offered for around $250, Acer's laptop for $350, and the Indian company called Novatium Solutions' basic "NetPC" for about $80.[80]

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Perhaps most impressive is the Indian government's announcement in May 2007 that it was supporting the development of a laptop that could sell for as little as $10.[81] Although this goal may be unrealistic, government-supported researchers already have designed a prototype that would cost about $47.[82] Some have argued conversations about $47 laptops in the context of the developing world where 3 billion people live off of less than $4 a day are premature. Clearly, not everyone on the planet is going to own a computer overnight, but any movement to reduce the cost barrier to computer ownership is an important step to closing the digital divide and expanding IT to the world's poor.

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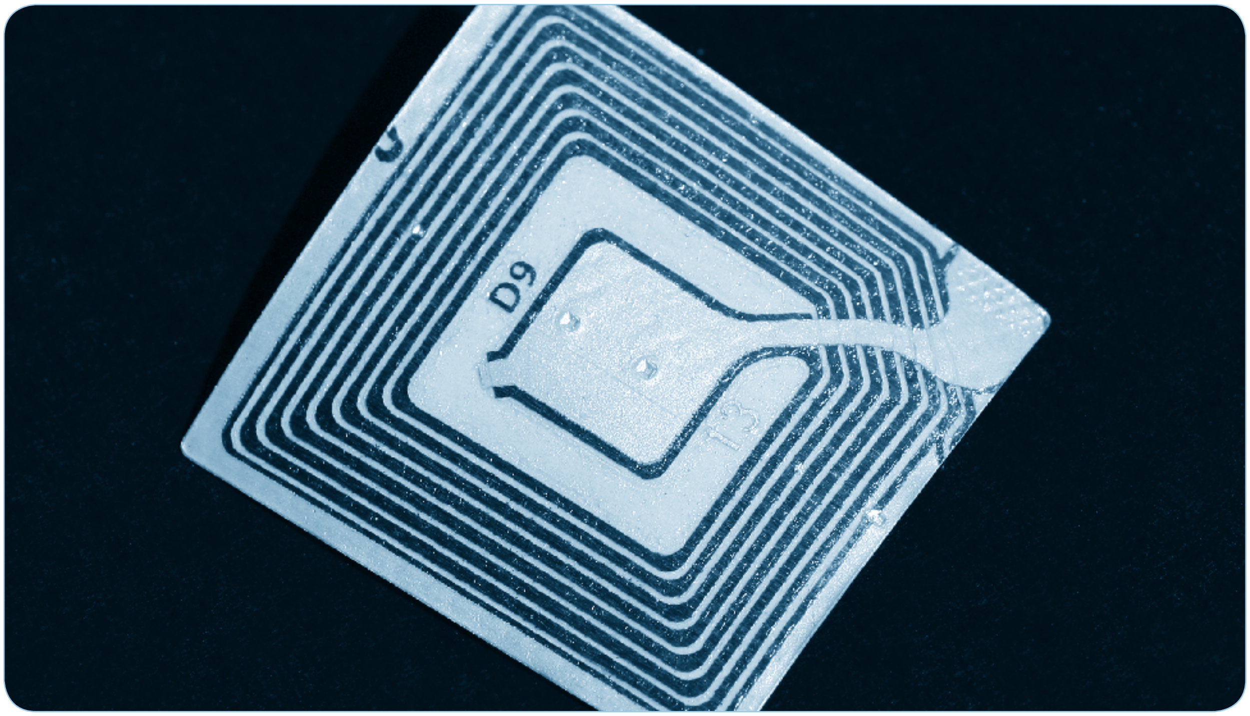
17. Challenges Moving Forward



Like any major new technology system, information technology (IT) brings with it not only vast benefits but also some costs. Automobiles, for example, brought unprecedented mobility and increased productivity but also brought pollution and accidents; overall, though, the benefits of automobiles greatly outweighed the costs. Similarly, IT's benefits have been vast and will continue to be; but at the same time, there are costs associated with IT that the industry itself, government, and citizens should continue to work to minimize.

As discussed below, challenges and costs associated with IT have arisen including issues related to privacy, information security, information overload, antisocial behavior, the digital divide, and e-waste. Yet the fact that there are challenges and costs associated with IT should not prompt policymakers to try to slow down digital transformation. Doing so would only minimize the significant benefits of a digital society.

As we consider the kind of future we want to live in, it is worth recalling what noted urbanist Lewis Mumford once stated: "Traditionalists are pessimists about the future and optimists about the past." In a world where the opportunities enabled by digital technology are so great, we cannot afford to have our policies guided by "traditionalists," if for no other reason than that the digital future is indeed bright.

Privacy

Perhaps the biggest barrier to more rapid progress toward a digitally enabled society is the fear by some people that this will entail the loss of privacy. Although IT is leading to vastly increased convenience, choice, and empowerment for individuals, some people see an IT-enabled world as a dystopia where our actions will be tracked by corporate or government leviathans. In this view, IT is stripping us of our privacy, exposing our intimate lives to anyone who wants to see them.

To be sure, as more and more information is in digital format, the ease of aggregating information and tying it to individuals has grown. The prospect of vehicle manufacturers installing dedicated short-range communication (DSRC) tags on every car, for example, begs the thorny question of who will have access to the tags, what they can do with the information, and whether access will require consent from the driver or vehicle owner. Will telematics be used to police violations of speed limits, red lights, and stop signs? Will parents be able to observe where and how their kids drive the parents' cars? How about wives and husbands? Will police have access to vehicle travel histories or real time access to vehicle locations for use in criminal investigations?

Civil liberties groups have objected to many applications of data mining because of privacy concerns stemming from the risk of data misuse. Some of their concerns arise from the fact that the government's data-mining projects involve data collected from both the public and private sectors. An additional concern is that the proliferation of digital information will lead to privacy violations by the government.

The suspension of the U.S. government's Total Information Awareness (TIA) data-mining initiative—eventually renamed the Terrorism Information Awareness Program—reflects the degree of public concern with government data-mining programs. The TIA program established by the Defense Advanced Research Projects Agency was discontinued early in the project's lifecycle, so the privacy concerns raised by civil liberties groups were primarily about potential risks rather than actual problems.

Although data mining does not provide investigators a crystal ball, it still can provide insights and clues into investigations. And the benefits of data-mining programs have not yet been fully explored. As data-mining techniques improve, with better data sources, refined algorithms, and lower false-positive rates, societies must continue to find the appropriate balance between privacy and security.

Privacy concerns associated with IT must be taken seriously, but it is important to keep a sense of perspective. Historically, major new technologies have prompted what in hindsight were overblown privacy fears. To cite an example, some people objected to easy-to-use cameras, fearing that individuals' activities would no longer be "private" when walking down the street.[1] Or to cite another example, when transistors were first developed, there was a short-lived privacy scare that everyone would be able to be snooped on using small electronic "bugs." In fact, *Life Magazine* had a headline on it "Insidious Inva-

The answer to many privacy risks is not to ban IT applications entirely, but rather to ensure that the appropriate rules governing privacy and civil liberties are in place and enforced.

sions of Privacy" and Congress even went so far as to hold hearings on the matter.[2] Of course, all this fuss was much ado about very little.

Society has always learned to manage the so-called threats in large part because of the fact that many—but certainly not all—of the concerns raised by privacy activists are hypothetical and speculative.[3] Given the large amount of information in digital format today, it is worth asking how much harm has been done to date. Notwithstanding all the fear and gloom from privacy activists, there simply have not been widespread privacy violations and of the privacy violations that have occurred recently, many have occurred precisely because the information was not in digital form.

The answer to many privacy risks associated with IT is not to ban IT applications entirely or to restrict them in ways that reduce their benefits, as some privacy advocates propose, but rather to ensure that the appropriate rules and practices governing privacy and civil liberties are in place and enforced. In most nations, a series of rules and laws govern how government actors can use personal data, electronic or otherwise. In fact, many of the privacy fears are not about technology, but rather about government access to sensitive information. The fact that more information is in digital form does not change this in any way.

Information Security

As the transition to a digital economy progresses, more and more processes will be completely electronic without paper records. Many people fear that in such an environment, information will not be secure. Moreover, as more people begin routinely storing and exchanging sensitive information online—including credit card numbers, banking information and health records—keeping digital information secure becomes increasingly important.

Fortunately, individuals and organizations are beginning to better understand the importance of implementing good information security practices. In fact, using good cryptographic techniques digital information can be made much more secure and trustworthy than its paper-based equivalent. Strong encryption algorithms help keep information private, digital signatures help authenticate online transactions, and biometric devices help authenticate users. In addition, computers' automatic logging systems help provide insight into security breaches, a safeguard typically only found on computer systems. If an employee snoops through confidential personnel records in the offline world, there is little evidence of this transgression; but if an employee opens a digital file containing the same information on a computer, the user, date, and time of access can all be recorded automatically.

Other security threats and annoyances to computer and Internet users include spam, malware, and phishing. These threats not only impede efforts to develop and deploy online applications but also impose substantial economics costs on individuals, businesses, and government. The worldwide cost of spam—unsolicited commercial e-mail—costs businesses \$50 billion worldwide in lost productivity and related expenses.[4] Similarly, the financial impact of malware—malicious software such as viruses, spyware, and adware that runs on a computer without the owner's informed consent—exceeded \$13 billion worldwide in 2006.[5] Phishing attacks—in which individuals fraudulently acquire sensitive information such as passwords and credit card information by masquerading as a trustworthy person or business in an electronic communication—has grown considerably, with 144 brands targeted by phishing in December 2007, a drop from the record high of 178 the previous month.[6]

Recognizing these problems, governments, IT companies and IT users are all working together to help reduce the costs of spam, malware, and phishing. Better software engineering practices have led to more robust applications that are more immune to the security flaws of the past. In addition, more secure operating systems have reduced the threat of malicious code corrupting a computer system.

One effect of the reliance on IT for much of modern life is the risk that critical information systems will become unavailable. Economies that rely heavily on connectivity to communicate with their global partners can suffer heavy losses when confronted with network or system outages. Threats to the availability of critical information systems and networks come from both intentional attacks and accidents. In April 2007, for example, following Estonia's removal of a Soviet-era war memorial, attackers mounted an organized distributed denial of service attack against the websites of government agencies, banks, newspapers, companies, and political parties—causing some of these websites to shut down for hours. Given Estonia's high level of dependence on the Internet for e-commerce and e-government, many feared further attacks could severely disrupt the country. In 2008, two underseas cables were damaged, reportedly by ships' anchors, resulting in a loss of Internet connectivity for large parts of South Asia. Given the importance of outsourcing for countries like India, the loss of these global telecommunication links was a cause for concern.

Just as accidents, crime, and natural disasters cannot be stopped in the real world, neither can engineers prevent all system failures and security breaches in the virtual one. Information security will continue to be an arms race between the good guys and the attackers. At the same time, however, the growing awareness of the importance of information security will lead to better information security controls and practices to reduce risk and improve response in case of a failure. In addition, increased governmental resources devoted to enforcement and prosecution of cybercriminals could help reduce the risks.

Information Overload

When asked to discuss the information society, many people's reaction is that it generates information overload: With access to information 24-7 from a wide variety of sources, some feel that the new digital society has become too rich in information. Saying "turn off your Blackberry" does not assuage many. But in fact, people do have choices, and as people become more used to living in a world where they can always be connected, it is likely that they, and organizations they work for, will develop mechanisms to manage their availability. Already, in fact, some companies are taking steps to limit 24-7 behaviors. The consulting firm PricewaterhouseCoopers has instituted a policy whereby workers accessing the corporate network on weekends are confronted with a message that discourages employees from sending e-mail.[8] Other companies have tried more radical policies such as creating "zero e-mail Fridays."[9]

And in some cases the answer to information overload is simply better technology to manage the flow of information. Numerous tools exist to help users organize their e-mails, documents, photos, and music, find information on their personal computer (PC), and generally be more effective at managing information. A tool released by Google called E-Mail Addict, for example, helps users limit their use of e-mail into more efficient time periods.[10]

Antisocial Behavior

IT has several aspects that raise the risk of facilitating antisocial behavior. First, using IT can be addicting and a form of social escapism. To be sure, high-profile cases—such as an addicted PC gamer in Korea dying after playing at a cybercafé more than 80 hours straight—suggest that for some individuals, PCs can be an antisocial source of escape.[11] But for other individuals, using the Internet can be a social opportunity to meet and interact with new people online. Massive multiplayer online games such as World of Warcraft, for example, connect millions of users from all over the world in an interactive virtual world. Some online games exist specifically for their social element, including the much-hyped virtual world Second Life. Indeed, for every case where IT might lead to isolation, there are many more cases where it enhances community. IT is a very powerful tool for enabling people with similar concerns (e.g., facing the same health problem) or interests (e.g., making films, engaging in political advocacy, enjoying music) to form meaningful online communities.

Second, because Internet communications seem to be a step removed from actual communications with individuals, the normal social graces most people practice when dealing with individuals face to face are sometimes absent. We see this in chat rooms, on blogs and in other digital communications, where insults and recriminations fly freely. We see it in the cyberbullying that goes on among not just some children and teens, but by adults. And the results can be severe, with some children committing suicide in response, and some adults like prominent bloggers Kathy Sierra and Blackamazon taking down their blogs after being attacked or receiving death threats. Because people have a sense of anonymity on the Internet, they behave in ways that they might otherwise never would if they were face-to-face with someone. Thus, one of the key benefits of the Internet, anonymity, is also a key challenge. It is not clear whether these kinds of antisocial and cruel behaviors are a result of an innate inclination by some people to be cruel and who can now do so with impunity, or whether it is a result of a new medium where new norms of acceptable behavior have yet to fully form.

Whatever the case, there is much more that society can do. Schools and parents can work to educate students on the risks of cyberbullying. Society can more actively take steps against children and teens who engage in such behaviors, behaviors that would never be tolerated in an adult workplace, and if necessary, provide the targets of such bullying with real choices for moving to different educational environments. And those actively engaged in digital forums need to more strongly enforce codes of civilized conduct, and shame and exclude those who practice extreme forms of behavior, just as we do in the offline world.

Finally, because the Internet is essentially a window into whatever individuals want it to be, it means that "bad parts of town" and "bad people" are now just a click away. While some kinds of content is illegal on the Internet in almost all nations (e.g., posting or viewing child pornography) much other content that the average person would view as offensive is not, from violence to racist speech to just plain bad behavior. For adults, this kind of content has always been available in one form or another, the Internet simply makes it easier to access. Short of trying to ban or block certain content (an albeit often difficult technical task), most societies will just have to live with this, and work to ensure that all citizens act in socially beneficial ways.

For children, the task is more complicated. In the old economy, a host of gatekeepers made it much harder for kids to be exposed to this kind of information. Here again, we are at the beginning of this process and as time goes on will learn to deal with it in more effective ways. Technology tools, like Web-filtering tools and monitoring will play a role. Windows Vista, Microsoft's latest operating system, for example, includes parental controls that let parents manage which websites, programs and games their children can access, set time limits on computer usage and generate an activity report of their children's computer usage. Other innovative tools, like Glubble, allow parents to create a "whitelist" of sites their children can access. With Glubble, if a child wants to go to a site not on her approved list, she can simply click a button to request permission from her parents; her request will pop up on her parents' computer—whether they are at home or at work—and her parents can then decide to approve or deny the website remotely.[12] Other content-filtering systems, like Open DNS, allow parents or corporate network administrators to filter content using more than 30 different categories. The Open DNS system relies on an active community of users that can submit tags to classify domain names based on their content.[13] But even with such tools, it is important to teach all children the rules of the road for operating in the digital world. Some schools have now put in place formal curricula to do just that. The Commonwealth of Virginia, for example, now requires all schools to teach Internet safety to their students.[14]

IT is a very powerful tool for enabling people with similar concerns (e.g., health problems) or interests (e.g., politics, films, music) to form meaningful online communities.

Complicating the situation even more is the fact that what is considered bad in one society is considered acceptable in another. When some individuals posted a YouTube video of the king of Thailand morphing into a monkey, for example, many Thai citizens were outraged, seeing this as an egregious insult to their revered monarch. Yet in the United States where the video was posted and hosted, people may not have agreed with the message of the video but they generally agreed with the right of the person to post the video as a fundamental right of free speech.

In the end, the answer is not global censorship; but neither should it be digital anarchy. Each nation should be allowed to manage Internet content in the ways it decides as long as it does not impose costs on those outside its nation, either by trying to require companies outside its nation to manage the content or restricting others outside their nation from viewing the content.

The Digital Divide

As we move to the digital information society, the ability for all citizens to access and understand information will be critical. If only a portion of society has access to information tools such as online learning, electronic health records, and e-government services, then society will move in direction of greater inequality.

Although the risk that some members of society will not be able to participate fully in the digital revolution is real, it is not necessarily a result that is set in stone. The history of virtually all consumer technologies shows the same pattern; early adopters tend to be more educated and wealthier, but as prices fall and ease of use goes up, these technologies become more widespread. We have seen this again and again with technologies like the radio, television, telephone, and, most recently, the cell phone.

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New digital tools are a bit different, however, in that they require a higher level of digital literacy. Learning how to use a cell phone, or at least how to call someone, is pretty straightforward. Learning how to use a computer and the Internet is less so. This suggests governments need to do a better job of facilitating digital opportunity. In South Korea, for example, the government has established digital literacy programs that target population groups that otherwise would be less likely to use the Internet. The "Ten Million People Internet Education Project (2000-2002)" worked to provide Internet education to approximately one-fourth of South Korea's citizens. In addition, the South Korean government has provided subsidies to around 1,000 private training institutes throughout the nation for the purpose of educating housewives. Under this "Cyber 21" program, the government offered 20-hour, week-long courses to housewives for only about $30. In just the first 10 days, 70,000 women signed up for the courses. The Korean Agency for Digital Opportunity and Promotion (KADO) also has a variety of programs to promote digital literacy and access to computers. These include establishing 8,263 local centers where the public can access the Internet for free, distributing free, used personal computers to individuals with disabilities and to those receiving public assistance, and education and training programs for older adults and individuals with disabilities.[16] Initiatives like these help close the digital divide and promote more equal digital opportunity.

Cybertribalism

In the old economy, people had significantly fewer choices than they do in the digital economy. And although the old economy may have limited individual choices, many argue that it promoted social cohesion. If everyone got the news from the same media outlets and got TV from the same three channels, it was easier to maintain a coherent society.

There is no doubt that the digital economy provides a vast array of choices—a situation that, by its very nature, means that individuals in a particular nation may be getting different information. But at the same time, individuals' ability to get information on their own from a variety of sources—and not mediated by powerful elites seeking to control a docile population—is breaking down more rigid, authoritarian societies.

Moreover, the very nature of the digital society is breaking down barriers across groups and nations, making people more and more citizens of the world. Because of the Internet, individuals are able to connect to others around the globe they might otherwise never encounter. As a result of IT, it is much easier to communicate with people from other nations and groups, to see and understand what is happening to them, and to essentially live in a cyber global village.

E-Waste

Although IT underpins advanced recycling applications, the disposal of IT hardware has lately become a cause for concern due in large part to toxic compounds, including heavy metals, contained in most IT hardware, which, if not properly disposed of, can leech into groundwater and the surrounding environment. The problem is not helped by the fact that IT equipment rapidly becomes obsolete because it improves so quickly, creating successive generations of so-called "e-waste." In fact, the United States generates between 1.9 and 2.2 million tons of electronics waste every year, 400,000 tons of which are recycled (2005 data).[17] Nor is the United States alone in generating large amounts of e-waste; it is estimated that Germany alone produced 1.1 million metric tons of e-waste in 2005.[18] One estimate pegs worldwide e-waste at 50 million tons annually.[19]

Governments and IT equipment manufacturers are tackling the environmental problems created by hazardous e-waste in two ways. First, companies are working to limit the use of hazardous materials in IT equipment, often in cooperation with government guidelines. Second, companies and governments are working together to recycle unwanted equipment. Many companies, including IBM, Dell, and HP, offer programs in which consumers can ship used equipment to them to be recycled for a small fee. Nonetheless, the extent to which consumers use such programs remains unclear, with some experts arguing that participation is quite limited.[20]

Various policies have been used by national and subnational governments to promote e-waste recycling. As of July 2008, 15 states in the United States had signed into law electronics recycling laws. The state of California, for example, began collecting a small fee for e-waste recycling from consumers in 2005 for every sale of a covered electronic device, including laptops and monitors. The money collected by the state is set aside in a fund used to offset the costs of proper collection and disposal of these products, which are no longer accepted with other household trash collection.[21] Other states have turned to a producer responsibility framework that requires IT manufacturers to assume the financial responsibility for recycling their products. The intent of this approach is to give manufacturers an incentive to make products that are cheaper to recycle (and have less toxic material), although its effectiveness has not yet been determined.

If not handled properly, the recycling process for IT products can be dangerous. Seventy percent of the world's recycled e-waste ends up in China, where, according to a recent study, it is often subject to improper handling, resulting in the leeching of heavy metals into the local environment. Recyclers disassemble discarded cell phones, televisions, computers, and other e-waste items in order to reuse the valuable metals contained within them, but they often do so without adequate safeguards for either personal or environmental safety. In one center of e-waste recycling, the town of Guiyu in southeastern China, for example, researchers have found that the community is highly contaminated with dangerous heavy metals. Dust from the Guiyu's roads contains lead levels 330 times and 371 times higher than lead concentrations in nearby communities that do not recycle e-waste.[22] Concentration levels for other metals, including zinc, nickel, and copper, are similarly elevated.

Clearly, discarded computer parts require delicate handling and proper disposal for the sake of both human health and the surrounding environment. Although the e-cycling chain in some nations appears to have inadequate safeguards to protect human health and the environment, electronic waste can be disposed properly, especially with the help of new and emerging recycling technologies. One example of a recently developed recycling process is an automated process for recycling printed circuit boards (computer innards that contain a wide array of heavy metals) that renders the components into salvageable bits of metal and plastic in an environmentally responsible way.[23] The recycling technique employs a two-step crushing process and magnets to separate effectively the various metals. This approach represents a significant environmental and efficiency improvement over other popular mechanical and chemical processes.[24]

In sum, although the sheer volume of e-waste presents an environmental challenge given its toxic nature, it appears that public awareness, governmental and corporate initiatives, and recycling techniques are finally beginning to catch up to scope the of the problem.

Conclusion

It has now been slightly more than a decade since the Internet became a mass phenomena and the digital economy began to take off. The United States, and indeed the world, have benefited greatly from the changes, with faster productivity and income growth, more innovation, higher quality products and services, and increased opportunity and convenience for hundreds of millions of IT users around the globe.

It is not clear how long IT will power economic growth, but it seems likely that for at least the next decade or two, IT will remain the engine of growth. The opportunities for continued diffusion and growth of the IT system appear to be strong. Many sectors of the economy, including health care, education, and government, have only begun to tap the benefits of IT-driven transformation. Adoption rates of e-commerce for most consumers, while rapid, are still relatively low. And the emergence of new technologies such as radio-frequency identification (RFID), wireless broadband, speech recognition programs, and others will enable still new IT applications.

In short, although the emerging digital economy has produced enormous benefits, the best is yet to come. The job of policymakers in developed and developing nations alike is to ensure that the policies and programs they put in place actively spur digital transformation so that all their citizens can fully benefit.

Endnotes

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