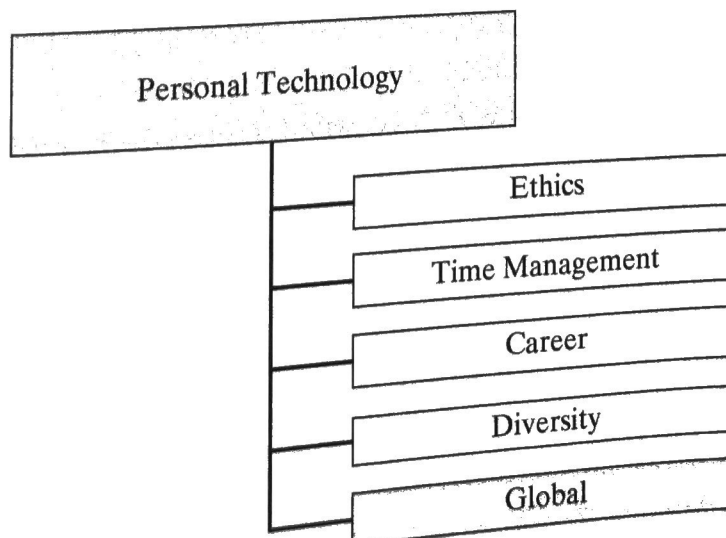


Globalization and Challenges for the Future

PREVIEW

Discussions of globalization have grown at a fast pace in the last decade and this chapter begins by discussing globalization and our *flattened* world brought about by many factors, including multinational organizations and the Internet. Japanese management styles and their utility for American companies are outlined. The significance of the European Union, the breakup of the Communist bloc, the BRICS countries, and the North American Free Trade Agreement are discussed. Next, problems and differences found in managing activities in third-world countries are outlined and an example of managing in Middle Eastern countries is given.

The second of the two major subjects of this chapter are the challenges for future engineers in the twenty-first century as proposed by The **National Academy of Engineering (NAE)**, a government-created non-profit institution in the United States. Through the engineering accomplishments of the past, the world has become flatter, more inclusive, and more connected. The challenges facing engineering today are not those of isolated locales, but of the world and the people of the world.



LEARNING OBJECTIVES

When you have finished studying this chapter, you should be able to do the following:

- Explain aspects of globalization.
- Discuss how the flattening of the world affects engineers.
- Discuss the challenges for engineers of the twenty-first century.

GLOBALIZATION

Two groups of topics are discussed in this section. First, trends in globalization, the nature of the multinational corporation, and their significance to the engineering career are considered. Second, the effect of cultural and economic differences on management is discussed, with special attention to management in Japan, Europe, and developing countries.

At the top political and economic level, **globalization** is the process of denationalization of markets, politics, and legal systems. Globalization broadly refers to the expansion of global linkages, the organization of social life on a global scale, and the growth of a global consciousness. The term is not neutral; different definitions express different assessments of global change. The following definition from globalization101.org represents a current view:

Globalization is a process of interaction and integration among the people, companies, and governments of different nations, a process driven by international trade and investment and aided by information technology. This process has effects on the environment, on culture, on political systems, on economic development and prosperity, and on human physical well-being in societies around the world.

People around the globe are more connected to each other than ever before. Information and money flow more quickly and easily than ever. The economic effect of globalization was felt during the 2008 to 2012 global financial crisis. Goods and services produced in one part of the world are increasingly available in all parts of the world. International travel is more frequent. International communication is commonplace. While some people think of globalization as primarily a synonym for global business, it is much more than that. The same forces that allow businesses to operate as if national borders do not exist also allow social activists, labor organizers, journalists, academics, and many others to work on a global stage.

As early as 1988, numbers of Japanese firms had begun exporting parts to the United States, assembling them here, then reexporting the product to Europe in an attempt to avoid European tariffs and quotas on Japanese-made goods! Partly as a result, by the beginning of 1987 Japanese companies in the United States already employed 250,000 Americans. Human societies across the globe have established progressively closer contacts over many centuries, but recently the pace has dramatically increased. Jet airplanes, cheap telephone service, the Internet, instant capital flows—all

these have made the world more interdependent than ever. Multinational corporations manufacture products in many countries and sell to consumers around the world. Money, technology, and raw materials move ever more swiftly across national borders. Along with products and finances, ideas and cultures circulate more freely. As a result, laws, economies, and social movements are forming at the international level. Many politicians, academics, and journalists treat these trends as both inevitable and (on the whole) welcomed. But for billions of the world's people, business-driven globalization means uprooting old ways of life and threatening livelihoods and cultures. The global social justice movement, itself a product of globalization, proposes an alternative path, more responsive to public needs. Intense political disputes will continue over globalization's meaning and its future direction.

However, the age of globalization has brought significant changes to the relationship between rich and poor states. In this new age, where the transfer of information to and from remote parts of the world is nearly instantaneous, U.S. corporations outsource significant portions of their manufacturing base to poorer countries around the globe. U.S. dominance of information technology serves as a tool with which it may exploit poor countries' low-wage workers, weaker environmental laws, and other factors to perpetuate its dominance of global markets. No longer are states in the periphery viewed as merely potential consumers of high-priced U.S. goods. They now serve as the inexpensive labor for the production of goods, including software, to be sold by U.S. manufacturers at higher prices in global markets.

Now offshoring and outsourcing (as referenced below in Thomas Friedman) are becoming more commonplace. As knowledge-based globalization expands, there are many reasons for these trends including the growing number of nations with increased technical skills, and a willingness of global corporations to locate facilities where profit opportunities exist. These offshore opportunities include: lower cost of labor, relaxed environmental standards, and nonexistent corporate tax structures. Thomas Friedman in his book, *The World is Flat*, has described this next phase of the global world as a flat world. Friedman describes 10 "flatteners" that he sees as leveling the global playing field:

The new age of creativity (the fall of the Berlin Wall), November, 1989. This event "tipped the balance of power across the world toward those advocating democratic, consensual, free-market-oriented governance, and away from those advocating authoritarian rule with centrally planned economies." When the Berlin Wall came down the citizens of the former Soviet empire were suddenly able to participate in the global economy. Friedman uses the fall of the Berlin Wall as a symbol for a general global shift toward democratic governments and free-market economies (where consumers determine prices based on what they are willing to pay) and away from authoritarian governments and centrally planned economies (in which prices are set by government officials).

The new age of connectivity (the rise of the Web). The Internet emerged as a tool of low-cost global connectivity. This event "enabled more people to communicate and interact with other people anywhere on the planet than ever before." Then the World Wide Web broadened the audience, followed by Netscape and then Explorer, which made the Internet accessible to everyone, from 5-year-olds to 95-year-olds. Standards emerged for e-mail, which increased the ability of computers and their users to share information over vast distances. Without the standardization, that information would have been forever marooned in the tiny networks scattered within businesses and universities.

Workflow software is the ability of machines to talk to other machines with no humans involved. Microsoft's monopolistic business practices, the widespread adoption of their Office software (Word, Excel, PowerPoint), has increased our ability to share and coordinate our work. Friedman believes these first three flatteners have become a "crude foundation of a whole new global platform for collaboration."

Open sourcing is the act of releasing previously proprietary software under an open source/free software license. Notable software packages that have been open sourced include: Netscape Navigator, whose code became the basis of the Mozilla and Mozilla Firefox Web browsers; StarOffice, which became the base of the OpenOffice.org office suite; and Wikipedia, which is written collaboratively by volunteers from all around the world; anyone can edit it. Since its creation in 2001, Wikipedia has grown rapidly into one of the largest reference websites, having attracted at least 684 million visitors yearly by 2008 in more than 260 languages. Instead of people just downloading music or news, they are increasingly likely to contribute information—writing a review of a product they bought on amazon.com, rating their professor at ratemyprofessor.com, or editing an encyclopedia entry on their favorite trivia topic on wikipedia.com.

Outsourcing allows companies to split service activities into components that can be subcontracted and performed in the most efficient, cost-effective way and then reintegrating their work back into your overall operation. Outsourcing includes services such as book production, accounting, and customer service.

Offshoring is manufacturing's version of outsourcing. Offshoring is when a company moves its production from its home country to another country, where it can be done with "cheaper labor, lower taxes, subsidized energy, and lower health-care costs."

Supply chaining allows horizontal collaboration among suppliers, retailers, and customers—to create value, resulting in "the adoption of common standards between companies" and more efficient "global collaboration." Supply chaining is an example of the flattening of the world because of the way it levels the boundaries between customers and manufacturers regardless of where in the world those manufacturers exist. This topic was presented in Chapter 11.

In-sourcing is distinct from supply chain management because it goes beyond supply chain management since it is third-party-managed logistics and requires more extensive types of collaboration. In-sourcing has become more common since 2006 as businesses had less than satisfactory experiences with outsourcing (including customer support). Many outsourcing proponents responded to a negative consumer opinion backlash resulting from outsourcing their communications management to vendors who rely on overseas operations. In-sourcing includes services such as accounting and customer service, as well as the manufacturing of parts.

In-forming. Google and other search engines are prime examples. "Never before in the history of the planet have so many people—on their own—had the ability to find so much information about so many things and about so many other people," writes Friedman. The growth of search engines is tremendous; for example take Google, which Friedman states is "now processing roughly one billion searches per day, up from 150 million just three years ago."

"The Steroids" are made up of specific technologies, supercharged by all the other flatteners. These include personal digital devices like mobile phones, iPods, personal digital assistants, twittering, instant messaging, and voice over Internet Protocol.

Multinational Organizations

A multinational corporation is one with significant operations in more than one country. Jacoby identifies six stages of multinationalization:

1. Exporting products to foreign countries
2. Establishing sales organizations abroad
3. Licensing patents and know-how to permit foreign firms to make and sell its products
4. Establishing foreign manufacturing facilities
5. Multinationalizing management from top to bottom
6. Multinationalizing ownership of corporate stock

A wide variety of factors makes international management more complex than single-country management. Robinson categorizes the important variables in the international system into six groups, based on differences in (1) national sovereignty, (2) national economic conditions, (3) national values and institutions, (4) timing of national industrial revolutions, (5) geographical distances, and (6) areas and population.

Pricing policies are a strategic tool of multinationals. One example is **transfer pricing**. For example, an automobile firm may produce an engine in country A, a transmission in country B, and assemble these into a car in country C. The price at which components are transferred to the assembly process determines where profits are accumulated and taxed and the level of import duties, yet often there is no competitive price for such components. Obviously, the countries losing revenue in this process may press for "more realistic" transfer prices. Multinationals also have engaged in *penetration pricing* to gain market share in a new market by unusually low prices. Japan and other Pacific Rim countries have been accused of *dumping* goods in the United States and Europe at prices far below their own internal markets, leading to legislation and quotas limiting such imports. In mid-1994, North Dakota farmers were accusing Canada of dumping durum wheat in the United States; Canadians replied that U.S. subsidies of wheat shipments to Europe left a shortage of wheat needed by U.S. spaghetti makers, which they were filling.

Japanese Management Styles

Ever since the Japanese began their ascendancy in the 1970s, an ocean of printing ink has been consumed in books and articles about Japanese management and cultural practices alleged to be at the root of their success. Among the practices most frequently mentioned, with some discussion of their implications, are the following:

1. Recruitment of employees directly out of secondary school or college, which (a) makes acceptance into a prestigious university critical, and (b) limits the opportunity for midcareer transfer to another company although the recent success of the *heddo-hantaa* (from the American "headhunter") in arranging midcareer movement of people with needed skills is moderating this.
2. The fabled lifetime employment of Japanese firms only applied to full-time male employees of the larger firms; at its peak in the mid-1970s it applied to only half of Japan's workers, and is estimated to be only half that now; nearly a fifth of the workforce is part-time (three-fold that of 20 years earlier) with no security (a practice that has recently increased in the

United States); further cutbacks are accommodated by bringing work in-house from sub-contractors or foreign plants. Still, in the recession of the early 1990s, the nominal Japanese unemployment rate of 2.7 percent (December 1993) included neither women, older workers who had given up hope, nor the estimated window tribe of 1.4 million office workers who sit by the window all day with nothing to do, reducing overall productivity.

3. Promotions are infrequent and based (along with salary) on seniority and teamwork, although Honda and other firms are now beginning to base bonuses on performance rather than seniority.
4. Retirement or restricted employment for older (55-year-old) workers, except for the few rising to top management; with a large aging population, this practice will give Japan serious problems.
5. *Michi*, or “the way” (to heaven or to corporate success), which emphasizes mastery of even a small task—a Zen philosophy of self-improvement to do the present job better, contrasted with the Western (and Confucian) emphasis on the next promotion.
6. *Giri*, a sense of duty of honor or obligation to observe community (read, company) customs; for the modern-day Japanese salaryman this may involve compulsory parties and unwanted assignments overseas or away from family, yet require loyalty to the company. Respected Japanese managers and technicians are *moretsu shain* (fanatical workers) and *yoi kigyo senshi* (good corporate soldiers), and thousands become victims of *karoshi* (death from overwork), leaving *karoshi* widows behind.
7. From the company in return, an almost womblike concern for the (full-time) worker, including family support, housing, recreational activities, social gatherings and cultural events, and festivities to commemorate promotion, internal transfer, and retirement, a security that has diminished in the recession of the early 1990s.
8. Ceremonies and rituals (such as group calisthenics and the company song) to foster love of company and group identification.
9. Rotation between functional departments to ensure broad exposure to the company (at the cost of the skills honed in specialization).
10. *Omikoshi* management, “the practice of having the middle [and lower] levels in the corporate organization . . . plan new projects on their own initiative, obtain top management approval for it, and then carry it out on their own . . . so that they carry the company like a group of people carrying the small portable shrine (*omikoshi*) that is a traditional feature of Shinto festivals.”
11. The *ringi* system of having people sign on the bottom-up proposals, after which responsibility for implementation is borne by the group rather than a specific individual.

These practices—although many now apply only to a minority of Japanese workers—are not without their problems. Odaka cites four disadvantages whose drawbacks have become increasingly obvious in the postwar years:

1. Encouraging employee dependency and suppressing individual creativity
2. Discriminatory employment and impediments to the formation of a free horizontal labor market
3. Harmful effects of the escalator system [in which those first on the employment escalator rise before later arrivals] and middle management promotion gridlock
4. Work that has no joy and seemingly has no meaning

Japanese management is moderating some of the sharpest differences from methods of Western management—the gradual, but slow, improvement in opportunities for women is a case in point. The Japanese postwar baby boomers, or *dankai sedai*, now in their 40s and 50s, are more affluent and better educated (especially in Western culture); as they gain ascendancy they are insisting on a balance between Western ideas and Japanese values. On the other side, leading American corporations have selectively adopted the most useful and transferable of the lessons from Japanese management.

Japanese production plants have several characteristics that set them aside from American competitors. Some of these have already been mentioned in earlier chapters: the almost fanatic emphasis on quality, the just-in-time approach that almost eliminates inventory on the plant floor, and the quality control circles and other devices through which the production employee directly works to improve the product. Others are a high priority on plant cleanliness, regarded as a prerequisite to quality; operating equipment below its ultimate capacity to extend its life and precision; automation and warning systems that require fewer workers; and a mutual trust (and unified language and ethnicity) that requires fewer management review levels.

Any of the management methods being successfully employed in Japan or other countries can be adapted to U.S. needs, and many of them were originally developed in the United States. As Drucker puts it, “What we can learn from foreign management is not what to do. What we can learn is to do it.”

European Union

The United States has long been the world's most attractive single market, with its quarter-billion affluent people in a single market free of internal barriers; it has therefore been a prime target of European and Pacific Rim manufacturers of every sort. On January 1, 1993, Western Europe was transformed into a market free of internal barriers that equals or exceeds that of the United States, with profound implications for international trade. The *Wall Street Journal* summarized these implications in early 1988:

The EC [European Community] may never become the United States of Europe its founders dreamed of in the 1950s. The Europe of 1992 will continue to differ from the United States of 1988. The 12 nations will still speak nine different languages, spend twelve different currencies in different ways, and be governed by different laws.

But as the EC enacts some 300 new rules aimed at dismantling virtually all intra-European trade barriers by the end of 1992, nearly every major European country is rushing to adjust to a future market of 320 million customers. Although nobody can predict all the winners and losers, it's clear that bigger, more powerful companies will arise in Europe and then move into world markets. At the same time, multinational companies, be they European, American, or Japanese, should find it simpler to manufacture and sell in Europe.

Today the European Union (EU), which has as its foundation the European Community, is an economic and political partnership between 27 democratic European countries. The results are frontier-free travel and trade for its 495 million citizens, the euro (the single European currency), safer food and a greener environment, better living standards in poorer regions, joint action on crime and terror, cheaper phone calls and air travel, and millions of opportunities to study abroad.

The euro (€) is probably the EU's most tangible achievement. The single currency is shared by 17 countries (2012), representing two-thirds of the EU population. Others will follow once their economies are ready. All euro notes and coins can be used in the countries where the euro is accepted. Each note is the same, while the coins have a common design on one side and a national emblem of their country of origin on the other side.

EU countries not using the euro: Bulgaria, Czech Republic, Denmark, Latvia, Lithuania, Hungary, Poland, Romania, Sweden, and the United Kingdom.

In today's competitive world, Europe needs new jobs and a skilled workforce. New jobs can come from research and development. EU leaders planned to increase research spending by more than 50 percent between 2001 and 2010. One-third of the EU's €115 billion-a-year budget is spent on attracting investments and creating jobs in disadvantaged regions, and training unemployed or under-qualified workers.

BRICS

The five BRIC countries of Brazil, Russia, India, China, and South Africa are distinguished from other promising emerging markets by their demographic and economic potential to rank among the world's largest and most influential economies in the twenty-first century (and by having a reasonable chance of realizing that potential). Together, the four original BRIC countries comprise more than 2.8 billion people or 40 percent of the world's population, cover more than a quarter of the world's land area over three continents, and account for more than 25 percent of global GDP. In 2010, South Africa became one of the BRICS countries. The BRIC countries of China, India, and Brazil account for much of the dramatic increase in science research investments and scientific publications. From 2002 to 2007, they more than doubled their spending on science research.

International Trade Agreements

In the past several decades, international trade and multinational management organizations have increased dramatically. From 1950 to about 1988, real U.S. gross domestic product (GDP) tripled, but real-world GDP quadrupled, and world trade grew sevenfold; NAFTA, WTO, World Bank, International Monetary Fund, and other trade agreements should assure that this continues. More and more American companies are finding that, even if they are not heavily involved in international markets themselves, they cannot escape the impact of international competition in their home markets.

North American Free Trade Agreement. Implementation of the North American Free Trade Agreement (NAFTA) began on January 1, 1994. This agreement removes most barriers to trade and investment among the United States, Canada, and Mexico. The United States and Canada have long been touted as having the world's longest undefended border. What few U.S. citizens realize is

that Canada is also our largest trading partner and Mexico is second, and from 1993 to 2007, trade among the NAFTA nations more than tripled, from \$297 billion to \$930 billion. U.S. manufacturing output rose by 58 percent between 1993 and 2006, as compared to 42 percent between 1980 and 1993. Manufacturing exports in 2007 reached an all-time high with a value of \$982 billion. Some States grew by 19.3 percent over the period of 1993 and 2007. During the previous 14 years wages had grown only 11 percent.

World Trade Organization. The World Trade Organization (WTO) is an international organization designed to supervise and liberalize international trade. The WTO came into being on January 1, 1995, and is the successor to the General Agreement on Tariffs and Trade (GATT), which was created in 1947. The WTO has nearly 150 members, accounting for over 97 percent of world trade. About 30 other countries are negotiating membership. The WTO is the only global international organization dealing with the rules of trade between nations. At its heart are the WTO agreements, negotiated and signed by the bulk of the world's trading nations and ratified in their parliaments. The goal is to help producers of goods and services, exporters, and importers conduct their business. The past 50 years have seen growth in world trade. Merchandise exports grew on average by 6 percent annually. Total trade in 2000 was 22 times the level of 1950. GATT and the WTO have helped to create a strong and prosperous trading system contributing to unprecedented growth.

Management in Developing Countries

Background. There is certainly a *world of variety* in the problems of managing activities in developing countries, which may be defined for our purposes as the entire world except for the United States, Canada, Europe, Japan, Australia, New Zealand, Russia, and a few other countries such as Israel and the most industrialized parts of Brazil and South Africa. The Pacific Rim countries of South Korea, Taiwan, Hong Kong, and Singapore are rapidly developing in a manner similar to Japan's development and will also not be considered further. Next are presented a few general concerns with operations in developing countries; these are followed by some specific comments on Middle Eastern countries as an unusual example.

Characteristics of Developing Countries. Third-world countries differ widely, but the following characteristics will be found in many of them:

1. A shortage of capital, often with financial resources controlled by a few families
2. Government planning of the economy, and frequently, government operation of utilities and major industries
3. A shortage of skilled workers, professionals, and support services
4. A high level of government control of foreign subsidiaries in terms of approvals to establish or modify business activities; import controls; currency exchange rates; control of repatriation of profits and capital; requirement of partial or majority local ownership of foreign subsidiaries; and taxation policies, including tax incentives

5. Different preferences regarding leadership style. Hofstede measured the "power distance" between the superordinate and subordinate (a measure of the extent of autocratic leadership style). For example, consider the following facts:
 - Five South American countries and Mexico had power distance indexes from 63 to 81, indicating an authoritarian style (Argentina was 49).
 - Five Romance-language European countries (Italy, France, Belgium, Spain, and Portugal) had indexes from 50 to 68.
 - Eight South and Southeast Asian countries ranged from 54 (Japan) to 77 (India).
 - The Philippines, both Asian and Spanish in influence, had the highest index (94).
 - The United States had an index of 40.
 - Nine Western and North European countries had indexes of 18 to 39, indicating a less authoritative style in these developed countries.
6. In many Asian and South American countries the family is paramount, and enterprises tend to be small, with management confined to family members.
7. While engineers from developed countries tend to specify the advanced technology they are familiar with for use in developing countries (and the host countries often encourage this), there is seldom a local ability to operate and, especially, repair such technology. Often a more *appropriate technology* is possible, which may be more labor intensive (not necessarily a penalty where labor is cheap and unemployment high), that can be used and maintained more easily.
8. Without long experience in an industrial economy, nationals (including government officials) may take a much more relaxed attitude about getting things done on time.

Ethical Considerations. Because cultures vary so much, engineering and managerial work in developing countries may involve ethical decisions that would not present themselves in the United States. For example, bribery of public officials may be a way of life and may be necessary to get permits issued or spare parts released from customs. Minor officials may be paid so little that to maintain a decent livelihood, they count on supplements that would clearly be illegal in the United States. Should the American plant manager participate? On a higher level, should a U.S. sales manager pay millions of dollars in bribes to top officials in a foreign government to facilitate sales of jet aircraft to the national airline, an illegal act under U.S. law, or abandon the sale to less fastidious competitors?

Plant operation presents its own questions. Should a U.S.-owned plant just maintain levels of pollution control and plant safety consistent with local requirements, or should the higher levels required in U.S. plants be maintained, at higher cost? To what extent should an American plant manager insist on equal opportunity regardless of race, religion, and genders in a society that distinctly discourages such equality? Like many of the issues in professional ethics discussed in Chapter 16, actual cases of such problems often do not have simple solutions.

A Middle Eastern Example. Since the countries of the Middle East enjoy half the world's petroleum reserves, they have been able to forge ahead with economic development at an unprecedented rate, and thousands of American, European, and other engineers have become acquainted with this very different culture. Actually, the Middle East is not a single culture, but varies from Egypt, Iraq, and Iran to the monarchy of Saudi Arabia. The discussion that follows relates to Saudi

Arabia and is based on conversations with engineering employees of the Arabian American Oil Company (ARAMCO) from America and Europe, and Saudi Arabia and other Moslem countries, who were students in classes taught by the author (Babcock) in Saudi Arabia in 1983 and 1985. The first American oil company engineers literally waded ashore and set up a tent camp in 1935 to begin exploration. At one time or another during the development of ARAMCO capacity, engineers faced the following types of problems:

1. Transportation and utilities, which one takes for granted, had to be developed from scratch by ARAMCO, the country, or both: Major water ports, roads, trucking capacity, railroads, and electric power—even fresh water was unavailable in acceptable quantities, and mammoth facilities to create it from seawater were built.
2. *Climatic effects.* Common summer temperatures of 120 °F limited human output; wind and sand on the desert and offshore weather and corrosion for oil wells in the Arabian (Persian) Gulf resulted in abnormal (and expensive) material specifications.
3. Remoteness from the U.S. (Texas) ARAMCO design headquarters led to shutdowns from parts shortages—reduced by locating immense quantities of parts inventory “in Kingdom” and dedicating a Boeing 747 to two weekly round trips to carry cargo and passengers from Texas to Dhahran (Saudi Arabia).
4. Communication timing problems due to the nine-hour time difference and the four-day “weekend” (Thursday and Friday in Dhahran, Saturday and Sunday in the West)
5. *Islamic law and culture*
6. *Political and governmental factors.* Boycotts on products and parts from Israel and specified companies elsewhere; priority on developing Saudi personnel for management and later engineering positions and for local subcontracting; and customs and other bureaucratic delays
7. Shortage of skilled labor, professionals, local suppliers, and contractors
8. Expatriate problems in hiring (lead time, premium pay, and restrictions on nationality, religion, and genders); impact of extended vacation schedules on management continuity; and integrating the multinational workforce with their different pay scales, languages, cultures, values, motivations, and work methods

These same problems will not evidence themselves in another part of the third world; there will, instead, be a different set. The engineer and manager who seek to operate in an unfamiliar environment must be very careful to become familiar with the local culture, politics, and people and learn to operate under these constraints; those who can do this effectively are of great value to their organization, and many find that they truly enjoy working and succeeding in different environments.

Significance for the Engineering Career

American engineers have been in demand internationally for a century and a half, especially since World War II. Many engineers have found they could earn up to twice as much abroad in places like Saudi Arabia, returning after as little as 15 years with a comfortable retirement. Engineers in truly global concerns like the large design and construction firms previously cited or manufacturers with half their sales overseas often find at least one international tour necessary to rise very far in the

firm. Again, many engineers find an international tour satisfies their desire for adventure, or returns them to the culture their family originated from, or adds an invaluable experience in the education and growth of their children.

There are negative factors as well. Companies who are not fully committed to global operations still send engineers and managers abroad, but when they return, the expatriates find they have been *out of sight—out of mind* and have lost momentum in their career. Two-career families may find that the career of the expatriate's spouse is "on hold" during the overseas period, and families with children in high school or college (or with elderly parents) may find being overseas disruptive. Today the young engineer needs to consider carefully what an international assignment will do for (or the harm it might do to) his or her overall career or progress within a specific firm, and the impact it might have on personal goals and family life.

ENGINEERING GRAND CHALLENGES

A diverse committee of experts in engineering and science from around the world was convened by the U.S. National Academy of Engineering and announced in February 2008, 14 challenges for engineers in the twenty-first century. As was pointed out in the previous section of the text the world has become flatter, more inclusive, and more connected. The Challenges belong to four realms of human concern—sustainability, health, vulnerability, and joy of living. The Challenges are as follows:

Sustainability

- **Make solar energy economical.** Sunshine has long offered a tantalizing source of **environmentally friendly power**, bathing the earth with more energy each hour than the planet's population consumes in a year. But capturing that power, converting it into useful forms, and especially storing it for a rainy day, poses provocative engineering challenges.
- **Provide energy from fusion.** Another popular proposal for long-term energy supplies is **nuclear fusion**, the artificial recreation of the sun's source of power on earth. The quest for fusion has stretched the limits of engineering ingenuity, but hopeful developments suggest the goal of practical fusion power may yet be attainable.
- **Develop carbon sequestration methods.** Engineering solutions for both solar power and nuclear fusion must be feasible not only technologically but also economically when compared with the ongoing use of fossil fuels. Even with success, however, it remains unlikely that fossil fuels will be eliminated from the planet's energy-source budget anytime soon, leaving their environment-associated issues for engineers to address. Most notoriously, evidence is mounting that the carbon dioxide pumped into the air by the burning of fossil fuels is increasing the planet's temperature and threatens disruptive effects on climate. Anticipating the continued use of fossil fuels, engineers have explored technological methods of **capturing the carbon dioxide** produced from fuel burning and sequestering it underground.
- **Manage the nitrogen cycle.** A further but less publicized environmental concern involves the atmosphere's dominant component, the element nitrogen. The biogeochemical cycle that

- extracts nitrogen from the air for its incorporation into plants—and hence food—has become altered by human activity. With widespread use of fertilizers and high-temperature industrial combustion, humans have doubled the rate at which nitrogen is removed from the air relative to preindustrial times, contributing to smog and acid rain, polluting drinking water, and even worsening global warming. Engineers must design **countermeasures for nitrogen cycle problems**, while maintaining the ability of agriculture to produce adequate food supplies.
- **Provide access to clean water.** Chief among concerns in this regard is the **quality and quantity of water**, which is in seriously short supply in many regions of the world. Both for personal use—drinking, cleaning, cooking, and removal of waste—and large-scale use such as irrigation for agriculture, water must be available and sustainably provided to maintain quality of life. New technologies for desalinating seawater may be helpful, but small-scale technologies for local water purification may be even more effective for personal needs.

Health

Advanced health informatics and **computerized catalogs of health information** should enhance the medical system's ability to track the spread of disease and analyze the comparative effectiveness of different approaches to prevention and therapy.

Engineer better medicines. Another reason to **develop new medicines** is the growing danger of attacks from novel disease-causing agents. Certain deadly bacteria, for instance, have repeatedly evolved new properties, conferring resistance against even the most powerful antibiotics. New viruses arise with the power to kill and spread more rapidly than disease-prevention systems are designed to counteract.

Vulnerability

- **Restore and improve urban infrastructure.** Even as terrorist attacks, medical epidemics, and natural disasters represent acute threats to the quality of life, more general concerns pose challenges for the continued enhancement of living. Engineers face the grand challenge of renewing and **sustaining the aging infrastructures of cities and services**, while preserving ecological balances and enhancing the aesthetic appeal of living spaces.
- **Prevent nuclear terror.** As a consequence, vulnerability to biological disaster ranks high on the list of unmet challenges for biomedical engineers—just as engineering solutions are badly needed to **counter the violence of terrorists** and the destructiveness of earthquakes, hurricanes, and other natural dangers. Technologies for early detection of such threats and rapid deployment of countermeasures (such as vaccines and antiviral drugs) rank among the most urgent of today's engineering challenges.
- **Secure cyberspace.** A prime example where such a barrier exists is in the challenge of **reducing vulnerability to assaults on cyberspace**, such as identity theft and computer viruses designed to disrupt Internet traffic. Systems for keeping cyberspace secure must be designed to be compatible with human users—cumbersome methods that have to be rigorously observed do not work, because people find them inconvenient. Part of the engineering task will be discovering which approaches work best at ensuring user cooperation with new

technologies. In sum, governmental and institutional, political and economic, and personal and social barriers will repeatedly arise to impede the pursuit of solutions to problems. As they have throughout history, engineers will have to integrate their methods and solutions with the goals and desires of all society's members.

Joy of Living

- **Reverse-engineer the brain.** An important way of exploiting such information would be the development of methods that allow doctors to forecast the benefits and side effects of potential treatments. **“Reverse-engineering” the brain**, to determine how it performs its magic, should offer the dual benefits of helping treat diseases while providing clues for new approaches to computerized artificial intelligence. Advanced computer intelligence, in turn, should enable automated diagnosis and prescriptions for treatment.
- **Enhance virtual reality.** Some new methods of instruction, such as **computer-created virtual realities**, will no doubt also be adopted for entertainment and leisure, furthering engineering's contributions to the joy of living. Advanced personalized learning and the external world are not the only places where engineering matters; the inner world of the mind should benefit from **improved methods of instruction and learning**, including ways to tailor the mind's growth to its owner's propensities and abilities.
- **Engineer the tools of scientific discovery.** The spirit of curiosity in individual minds and in society as a whole can be further promoted through engineering endeavors **enhancing exploration** at the frontiers of reality and knowledge, by providing new tools for investigating the vastness of the cosmos or the inner intricacy of life and atoms.

FUTURE CONSIDERATIONS IN ENGINEERING AND MANAGEMENT

Future directions in engineering and management are, of course, inseparable from future trends of society as a whole. Some of the driving forces affecting the beginning of the twenty-first century include the following:

- Continuing computer-based information revolution
- Increasing technological sophistication of society
- International and political considerations in a shrinking, interdependent world
- Demographic considerations
- Interactions of food, energy, materials, and the environment

The Information Revolution

We are in the early phases of the knowledge management revolution, which is just as significant to world history as was the industrial revolution that preceded it.

- **The virtual organization.** The availability of integrated management information and decision-making systems, together with user-friendly software and increased computer literacy among managers, has decreased the number and levels of middle managers and staff professionals. Yet the empowerment and responsibility of nonmanagers has increased. As members throughout an organization more and more share common purposes and a common information system with trusted suppliers and customers, boundaries between them will become more fluid as they participate in virtual teams, and they will become interdependent members of the new *virtual organization*. Ultimately, the lessons learned in reducing hierarchy, breaking down functional boundaries, and empowering individuals in profit-making industry will find real (but perhaps more limited) application in government, military organizations, and academia.
- **The virtual product.** The traditional practice of manufacturing standard goods for inventory and ultimate sale will increasingly disappear. Designs and specifications for families of *virtual products* will continue to exist in computer memory, and they will be transmitted to computer-integrated manufacturing systems when needed and as specified by the customer. The need for repetitive labor in manufacturing will continue to decline, and the availability of inexpensive labor will become less critical than the availability of knowledge workers in determining industrial locations.
- **The home.** The computer and information revolution has already begun to affect the way we live, and we can expect that it will do so increasingly. Computer systems in the home can be expected to handle home security, climate control, and optimization of energy use. Computer, mobile devices, television, and telephone will blend into a total system that connects us with the rest of the world for communication (oral, visual, and written), education, and interactive banking, shopping, and entertainment.

Education and the Technological Society

To function effectively in this technological society will require a more general understanding of technology. Education to prepare for this world will require a good understanding of mathematics and science and a widespread computer literacy. Such a change can be only gradual, since elementary and secondary school teachers are, in general (at least in the United States), poorly prepared in such areas. However, we can speculate on the age when something close to an engineering education will be the standard for an educated person—especially the policymakers who control society.

The Flattened World

The world has become flat and is becoming flatter. Trade is increasing internationally with fewer trade restrictions. There will be a continuing increase in the size and ubiquity of the great multinational companies, to the point that the determination of “what country they belong to” will become more and more uncertain. Clearly, the engineering manager of the future will need a much greater world view in designing, manufacturing, and marketing products.

Demographics

The increasing demand for knowledgeable workers will hasten the integration of women and minorities in all levels of our economy, especially in engineering, and in all levels of management and government. New approaches in childcare, part-time work, and work at home may accompany this. The increase in elderly citizens will begin to blur the age of retirement, with some workers retiring early and beginning a second (possibly part-time or entrepreneurial) career, while others continue with their employer in at least a limited way into their 70s. While medical science (and engineering) continues to find cures that keep us alive longer, the increasing burden of the aged on the working population will expand the ethical decisions that medicine must face.

Food, Energy, Materials, and the Environment

While birthrates can be expected to decrease as countries develop, world population will place increasing demands on static or decreasing farmlands and especially on diminishing natural resources of fossil energy and minerals. As industrialization continues to spread and the rain forests disappear, world problems of air, water, and thermal pollution can only increase. We can expect continuing pressure for energy conservation, and perhaps a grudging reemphasis in the United States on nuclear power to avoid the air and water pollution from fossil fuels, unless fusion energy is proven both feasible and economical. All of these problems present difficult decisions in public policy at local, national, and world levels. They also offer endless challenges to be met by the engineer and the engineering manager.

Changes in the Engineering Career

As a result of the decline of middle management in the industrial organization, engineering (and other) specialists can expect to spend a longer portion of their career working as professionals before being considered for management positions, but they will need some understanding of other specialties and of management's concerns while working as a team member.

Engineers will find their careers less stable than in previous generations. Bahrami explains:

Many firms have reexamined their employment policies—initiating early retirement programs and other incentives to reduce the size of their workforce. As pointed out in other studies, the critical tradeoff in this context is between corporate flexibility and individual security. Many corporations rely on temporary workers, specialized vendors, and consultants in order to flexibly deal with unique contingencies. Additionally, this trend points to a fundamental shift in the foundation of employer–employee relationship, away from the traditional patriarchal orientation toward what may be characterized as a peer-to-peer relationship. This sentiment is echoed in the following comment which encapsulates the implicit relationship between Apple Computer and its employees: “You own your own careers; we provide you with the opportunity.”

Engineers will therefore have to manage their career progress more than ever before. Because of rapidly changing technology, they will need to emphasize lifetime learning, not only in formal coursework but also by spending much more time following changes in their specialty, their industry,

and general business trends. Design engineers will find that the evolution of computer-aided design makes them more efficient and productive; as long as they continue to master new tools—but more vulnerable if they do not, since fewer designers may be needed. And, like production workers, they will find that they are competing in a global market, and that modern communication permits engineering to be integrated across the globe. Texas Instruments has been designing integrated circuits in India since 1986 (taking advantage of the world's third largest pool of scientific and engineering talent—after the United States and Russia—who uniformly speak English); Sun Microsystems has hired Russian scientists for software and microprocessor research; CrossComm Corp. has their communications software written by Poles at the University of Gdansk.

In conclusion, engineers are a key element today in the role that the United States must play to keep manufacturing leadership and a sound economy while mass production shifts. The world has become flatter, more inclusive, and more connected. The challenges facing engineering today are not those of isolated locales, but of the world and the people of the world. To fit into this world, the engineer needs to remain alert to changing products, processes, technologies, and opportunities and to manage the progress of his or her career. These engineers will find the twenty-first century exciting and rewarding.