FUTURE OF MANUFACTURING IN THE U.S.

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EXECUTIVE SUMMARY

Back in the 1950’s, manufacturing was responsible for about 19% of gross domestic product (GDP) and employed some 30% of the workforce. Today, it is estimated to account for 11-17% of GDP, 13% of the workforce and some two-thirds of the nation’s industrial R&D. Although the U.S. continues to be the leading producer of high technology products, the question is now frequently raised as to whether manufacturing will continue to be the most important part of a world-class economy. To some, the answer must be an emphatic yes. To others, manufacturing is bound to lose its prominence as global competition shifts manufacturing action to low wage producers and emerging markets. To others yet, the answer depends on the ability of the traditional manufacturing industry to espouse a new business model where “the starting point is not making the good but service to enable the customer to get the fullest benefit from the goods” [Drucker, 1998]. It is within this continuing debate that this study was undertaken with the objective of developing a framework for evaluating future manufacturing businesses in the U.S. A simple framework was proposed and manufacturing businesses examined in light of it.

As a first step, a future that was not too distant (2010-15) was selected as a rough target to enable the focus to be on trends and responses that were already emergent and with impacts that were predictable with reasonable accuracy. A prospective evaluation was then undertaken to identify and evaluate a set of global environment drivers, that is external drivers, with the potential to influence the manufacturing firm in the future but which are outside of the firm’s control. Identified drivers include globalization, ecological awareness, demographics and technology.

Globalization in this context was interpreted to refer to the current and future state of world dynamics where the effect of developments in one part of the world quickly propagates to other places around the planet affecting the lives and activities of people. Three manifestations of globalization were selected for review. They include the proliferation of trade agreements, the emergence of the European Union as an economic and regulatory bloc and the rise of China as a major global manufacturing hub.

Trade liberalization beginning in the 1970’s and exploding in the 1990’s is allowing multinational corporations, transnational corporations and even small national companies to move manufacturing production to where they can take advantage of factors including low wages and other compensation obligations such as pensions and health care, financing subsidies and loan guarantees offered by foreign governments, emerging high technology countries, lower taxation and regulatory constraints, closeness to the markets where the goods are sold, lower exposure to exchange rates and easing of trade friction. This dynamic allocation and re-allocation of manufacturing production to locations that provide a competitive advantage to the firm are expected to continue in the future in spite of labor and political calls for protection of local manufacturing jobs and the problems posed for low skilled workers. Competition from low wage producers and emerging high technology exporters is also expected to continue to exert pressure on U.S. manufacturing
jobs. Trade liberalization will also provide increasing opportunities for U.S. manufacturing exports.

The recent expansion of the European Union (EU) from 15 to 25 nations brings the total population of the economic bloc to 455 billion and a GDP on par with that of the U.S. The effect of the EU on the future of manufacturing is expected to continue to be felt at several levels. On the regulatory front, recently adopted restrictions on the use of hazardous materials in electronic products due to take effect on July 1, 2006 are sending worldwide manufacturers scrambling for alternative materials (solder, e.g.), products and processes. More sweeping regulations in the chemical area are under consideration. On the industrial front, the type of industrial policy practiced by some EU countries which gave rise to Airbus has already had a significant impact on aerospace manufacturing in this country. Airbus has grabbed a bigger share of the civilian aerospace market than Boeing and is poised to pose an even bigger challenge in the future. This type of industrial policy is being contemplated in fields such as pharmaceuticals, shipbuilding and mass (rail) transportation. Finally, the EU science and engineering infrastructure has now surpassed the U.S. in the production of science and engineering articles, and countries such as Ireland have emerged as leaders in new technology development, manufacturers and exporters.

Economic liberalization steps which established the joint venture law in 1979 and then special economic zones in 1980 have allowed China to emerge as a manufacturing export power with the largest trade imbalance with the U.S. China has essentially displaced other Asian countries such as Hong Kong, Taiwan and Korea as major exporters to the U.S. of labor intensive goods such as footwear, toys, sporting goods and games. It has expanded the manufacturing dominance to electronic products and is now moving to include information technology products. Contracted foreign direct investment (FDI) which averaged about $3 billion/year in the 1980’s soared to $111 billion in 1993 and surpassed FDI inflows into the U.S. in 2002. The expectation is that both U.S. and foreign manufacturing firms will continue to use China as a hub for labor intensive manufacturing and potential markets in spite of the loss of manufacturing jobs in the U.S. China’s manufacturing aims, however, extend far beyond labor intensive, low technology manufacturing. It is slated to become a huge market for automobile consumption and export with an increasing impact on scores of small manufacturing enterprises (SMEs) which now supply the U.S. automotive market. It has also initiated joint ventures into some of the most delicate manufacturing technologies such as fifth generation TFT-LCD lines. China however still faces daunting economic, social and political challenges. U.S.-based manufacturers who have or plan to enter into supply relationships with China must weigh the impact of potential future disruptions on their operations.

Ecology deals with the complex of relations between living organisms and their environment. The manufacturing industry is a major consumer of resources and a producer of goods and waste that interact with the environment. Spectacular market failures in the past including mercury, polychlorinated biphenyls (PCBs) and other toxic contamination of the environment and the use of harmful substances such as asbestos in manufactured goods have increased ecological awareness and spawned a number of regulatory and legislative actions; these regulations impose a heavy burden on
manufacturing firms. SMEs will be most vulnerable because of limited resources and uncontrollable pressure through the supply chain. Proactive companies will seek to use regulatory constraints as a competitive advantage by developing innovative ecologically tolerant product and process strategies. SMEs with fewer R&D resources, smaller market share or a less progressive approach risk losing access to markets and customers.

Demographic changes in the coming decades will also impact the future of manufacturing. Changes in the size, composition and educational aptitude of the workforce are expected to pose a significant challenge to the future of manufacturing. A reduced rate of increase in the workforce, “graying” of the workforce due to the aging baby boom generation, and a persistent or deteriorating skills gap are the main concerns. They will affect the way companies hire, train, retain and compensate their future workforce. The mix and demand for goods and services is also expected to be affected by demographic changes with increased demand for health care goods as well as for products designed for safety, comfort and assisted use.

Technological innovations have had, throughout the last two centuries, a profound and disruptive effect on the manufacturing of this country and the world. Technology is expected to continue to be a major driver of the future of manufacturing. A set of potential technological drivers, which are already emergent in some of today’s manufacturing activities are reviewed in this report. Hydrogen fuel cell technology can potentially tackle two national problems: dependence on foreign oil and the environmental impact of fossil fuel combustion. If successful, it will significantly alter the balance of materials, processes and assembly lines devoted to the production of internal combustion engines it seeks to replace. The second technology, radio frequency identification tags, concerns tiny electronic devices which can carry information and can be interrogated by a non-contact reader. They can be embedded in a wide variety of products with potential applications in the manufacturing, distribution, service and after life disposal of these products.

As a second step, another prospective evaluation was carried out to identify emergent plausible strategic responses that manufacturing firms are taking in response to the interrelated set of global environment drivers identified in the first step. A set of six potential strategic responses is identified and five of those are reviewed below.

Shedding of Physical Assets – Traditional product manufacturers with mature technologies subject to increased global competition, over capacity, price pressure and other market challenges will seek to exit asset-intensive, low margin activities. In this scenario, companies will seek to replace company-owned manufacturing with outside supply chain management while investing in intangible assets such as knowledge and brands. The trend is clearly manifest in aerospace, automobile and semiconductor industries and creates both challenges and opportunities for SMEs.

Bundling of Goods and Services – As Peter Drucker observed, companies will look to restructure themselves into “Systems Companies in which the starting point is not making the goods, but service to enable the customer to get the fullest benefit from the goods.”
Examples include traditional automobile companies as transportation services companies, makers of jet engines and power turbines as sellers of “power by the hour” and computer manufacturers as sellers of “on demand” computing. This approach goes beyond conventional servicing of products. It is predicated on adding functionality, delivery performance guarantees and capturing more of the product life cycle revenue.

Flexibility and Mass Customization – Nearly a century ago, Henry Ford is reported to have said that “The customer can have any color as long as it is black.” Today and in the future, market pressures, intense competition, shifting customer preferences and the high cost of traditional product changeover will push industry to be at the forefront of innovation to acquire the flexibility required to shift away from mass production towards mass customization of products.

E-Collaboration – Globalization, increased competition, shifting customer preferences, increasingly complex mass customized products and other market forces are forcing companies to resort to complex matrix organization structures, joint ventures, partnerships and other forms of value networks. These actions in turn bring with them additional challenges such as coordination of activities, goal alignment, information sharing, collaborative designs and supply chain management. E-Collaboration and associated software and hardware tools will offer businesses a way to perform some of these tasks efficiently and gain competitive advantage.

The **third and final step** of our approach draws upon the information gathered in the first two steps to shift from a descriptive perspective to a normative one. Our normative perspective focuses on key findings extracted from the prospective evaluations described above, followed by a summary of futuring considerations and challenges to assist SMEs in their preparation for future opportunities. These challenges cover customers and markets, human resources, alliances and network, and technology development, access and awareness. They are summarized on the following pages.
## CUSTOMERS and MARKETS

### Key Futuring Considerations
- Product perception is evolving toward modularized, ecologically tolerant and customized products designed to serve global markets.
- Demographic trends will favor an aging and affluent group with preference for assisted use of goods, increased service and healthcare products.
- The proliferations of the Internet and Electronic Commerce have increased consumer awareness of a growing range of products and services worldwide.
- Globalization and proliferation of free trade enable businesses to access new markets and customers. They will bring increased competition and opportunities.

### Challenges for SMEs
- New product development should consider
  - Ecological awareness for competitive advantage and market access
  - Mass customization potential for differentiation and higher profit margins
  - Demographic trends and an aging population
  - Inclusion of services with goods for differentiation and customer lock-in
  - Vulnerability to global competition and low wage producers
- Global strategy for access to new markets should
  - Target companies which manufacture in the U.S. and exploit the competitive advantage of proximity, access and privileged market and product knowledge
  - Export or sell to companies with a strong export focus by identifying and adopting best business practices of successful exporters and seeking export guidance from available government and business advisory services.
- Leverage the Internet and E-Commerce for customer access

## HUMAN RESOURCES

### Key Futuring Considerations
- Expected decline in the growth rate of the U.S. workforce may create labor shortages and increased competition for skilled workers.
- Demographic trends will cause greater participation of people 55 and older in the workforce.
- Demographic trends will also bring in greater participation of women and minorities in the workforce
- Expected persistence of a skills gap in the workforce.

### Challenges for SMEs
- Develop innovative strategies to retain an older workforce by
  - Rethinking early retirement packages
  - Developing innovative health and benefit packages
  - Rethinking compensation and work schedules
- Develop innovative hiring strategies to attract women and minorities
- Develop innovative learning and training programs
- Increase the use of innovative automation to counter labor shortages and business cycle fluctuations
### ALLIANCES AND NETWORKS

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<th>Challenges for SMEs</th>
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<td>• Large companies will shed physical assets and exit asset intensive, low margin activities creating new opportunities for nimble small businesses and alliances of such businesses.</td>
<td>• Identify key resources and core competencies that would attract partnerships and alliances.</td>
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<td>• Rapid rate of technological change and high risk of obsolescence due to global competition make alliances and networks highly likely and desirable.</td>
<td>• Identify shortcomings in capability that would benefit from partnerships and alliances.</td>
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<tr>
<td>• Cooperative strategies have the potential to help small firms acquire required resources, access new technology and markets, and spread the risk over several partners.</td>
<td>• Seek out, evaluate and select potential partners.</td>
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<td>• Determine the most suitable type of cooperative alliance for your business. Consider joint programs/contracts, joint ventures, minority equity investments, licensing agreements and other types.</td>
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<td>• Develop and implement a plan that defines clear objectives, responsibilities, accountability, performance measures and reporting methods, protection of intellectual property, financial and legal issues, periodic reviews and strategy sessions.</td>
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### TECHNOLOGY DEVELOPMENT, ACCESS AND AWARENESS

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<td>• An increasing amount of technology that provided SMEs with a competitive advantage in the past is now widely accessible to foreign competition which, in some cases enjoys a considerable labor cost advantage. More nations all over the globe have invested and built significant technological infrastructure, R&amp;D capability and are now competitors for even the most advanced manufacturing technologies.</td>
<td>• Develop strategies to identify, invest in and acquire core technologies.</td>
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<td>• High technology and particularly disruptive technologies will be a major driver of future manufacturing.</td>
<td>• Consider cooperative agreements with research centers at Universities, Technology Transfer offices, Government laboratories and Government Programs for technology awareness and diffusion.</td>
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<td>• SMEs need to acquire the means for new technology awareness, development and acquisition.</td>
<td>• Consider a presence next to successful technological clusters in firm’s field or with technology related to its products and markets.</td>
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<td>• Consider cooperative alliances with other firms to access new technology.</td>
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1. OBJECTIVE AND APPROACH

The objective of this project is to develop a framework for examining and evaluating future manufacturing businesses in the United States. As a first step in this process, an exhaustive review of the relevant literature was carried out to evaluate approaches and findings on the topic at hand. Our search revealed that a considerable amount of attention has been devoted recently to this subject as many governments, industries, think tanks, consultants, the press, academic researchers and communities feel the effect of current trends and want to prepare for future opportunities. The search shows a breadth of effort at both the national (e.g., Visionary Manufacturing Challenges 2020) and international (e.g., European Union Futman Reports) levels by governmental and non-governmental entities through formal multi-year studies, forums, discussions and press reports. By far the most comprehensive and focused studies encountered to date are those sponsored by the European Union under The Future of Manufacturing in Europe 2015-2020: The Challenge For Sustainability.

The first of these EU reports, *Industrial Approaches-Transformation Processes* [Fraunhofer Institute, 2003a] covers “all design, planning and production processes in between the material production and the finished product (process manufacture, discrete manufacture, assembly, disassembly and remanufacture).” The second report, *Materials* [Fraunhofer Institute, 2003b] provides “a prospective analysis of emerging technological developments and interactions in the field of materials, as well as the strength and weaknesses of European Technological Competencies.” The third report assesses *The Future of the European Automotive Industry - Personal Cars* [Fraunhofer Institute, 2003c] by way of a focused case study.

The comprehensive nature, quality and availability of these studies and reports makes our original first step intention to carry out a prospective investigation of manufacturing developments and manufacturing technology interactions somewhat redundant. The vast commonality of material transformation processes and business issues between Europe and the U.S. to be gleaned from a prospective evaluation of the open literature and press material does not seem to warrant an additional effort which would undoubtedly be somewhat duplicative.

Our next step then was to move to postulate a framework for evaluation of manufacturing businesses of the future as a three (3) step process.

**Step 1: GLOBAL ENVIRONMENT:** In this step, a prospective investigation of available information was carried out to identify a set of dominant external drivers that can influence the manufacturing firm of the future but which are outside of the firm’s control. Drivers retained under this global environment step include globalization, ecological awareness, demographics and technological developments.
Step 2: STRATEGIC RESPONSES: This second step follows with another prospective analysis to identify plausible strategic responses that manufacturing firms might take or the steps already under way to respond to pressure of the global environment drivers of step 1. Responses identified and retained at this point include the shedding of physical assets, bundling of goods and services, manufacturing flexibility and mass customization, e-collaboration via leveraging of the Internet, ecological design of products, and product and manufacturing innovation.

Step 3: SME RECOMMENDATIONS: In this final step, we shift from a descriptive perspective to a normative one. Our normative perspective focuses on key futuring considerations and recommendations to assist SMEs in their preparation for future opportunities. These recommendations include human resources, customers and markets, alliances and networks, and technology developments, access and awareness.

Figure 1.1 shows a conceptual view of the elements contained in the framework and Figure 1.2 provides an expanded itemized view of global environment drivers.
PROPOSED FRAMEWORK

GLOBAL ENVIRONMENT

GLOBALIZATION
ECOLOGICAL AWARENESS
DEMOGRAPHICS
TECHNOLOGY

SHEDDING OF PHYSICAL ASSETS
BUNDLING OF GOODS AND SERVICES
FLEXIBILITY AND MASS CUSTOMIZATION
E-COLLABORATION
ECOLOGICAL PRODUCT

SME RECOMMENDATIONS

CUSTOMERS AND MARKETS
HUMAN RESOURCES
ALLIANCES AND NETWORKS
TECHNOLOGY DEVELOPMENT
ACCESS AND AWARENESS

Figure 1.1 – Framework Diagram
GLOBAL ENVIRONMENT

- **GLOBALIZATION**
  - Easier global access to information and technology
  - Shifting global distribution of skills
  - Shifting economic power and investment
  - Emergence of China, India and other competitors

- **DEMOGRAPHICS**
  - Change in population size
  - Change in age and income distribution
  - Supply of skilled and unskilled labor
  - Demographic influence on product perception
  - Brain drain and reverse brain drain

- **TECHNOLOGICAL DRIVERS**
  - Emerging material and process technologies
  - Substitution technologies
  - Pace of technological change
  - Product tracking technologies

- **SOCIO-CULTURAL DRIVERS**
  - Evolving perception of products/services
  - Mass customization of products
  - Ecological awareness: Environment/Sustainability

- **POLITICAL / LEGAL AND ECONOMIC DRIVERS**
  - Regulation / deregulation
  - Taxation and health costs
  - Trade agreements and export controls
  - Currency policy and currency swings
  - Competitive trade policies and incentives
  - Government procurement policies
  - Defense procurement / Homeland security

*Figure 1.2 – Global Environment Drivers and Factors*
The rest of this document is organized as follows. Section 2 presents a sample of opinions on the current and future state of manufacturing that were expressed by a wide range of private and public figures and institutions. These opinions are then followed by a presentation and discussion of a set of global environment drivers that we believe will exert considerable influence on the future of manufacturing. The focus then shifts to current or emerging strategic responses that companies have developed as a result of the emerging global environment drivers. The third and final step of the approach will use the information from the global environment drivers and strategic responses to craft futuring recommendations to SMEs. The document concludes with some recommendations for further study.
2. SAMPLE OPINIONS ON THE CURRENT AND FUTURE STATE OF U.S. MANUFACTURING

The substantial loss of jobs (by some estimates 2.7 million over the last three years) in the manufacturing sector has generated plenty of interest from a wide range of parties directly and indirectly affected by the state and future of manufacturing in the U.S. This section presents a sample of such opinions that were expressed in position papers, the press, government agency writings and other media. Some of these opinions were found to be of particular interest to the topic and objectives of this report and they are reported here for information purposes. These views are not reported in any order of preference and in some instances, liberty was taken to present the views of some individuals or associations in their own words as exhibits so that their message does not get diluted by our interpretation and so that the reader experiences the articulate and sometimes colorful ways used to express those views. Sample opinions selected for this report include the following:

- The view from the National Association of Manufacturers (NAM)
- An opinion from Peter Drucker
- Comments from George Akerloff, Nobel Laureate in Economics
- The position of Bruce Bartlett, National Center for Policy Analysis
- The position of Gregory Tassey, Senior Economist at NIST
- Comments and advice from Bruce Braker, President-Tooling and Manufacturing Association (TMA)
- The thoughts of Representative Donald Manzullo (R-IL), Chairman of the House Small Business Committee

2.1 The View from the National Association of Manufacturers

The National Association of Manufacturers [National Association of Manufacturers, 2004] has been a vocal and articulate proponent of the importance of manufacturing jobs to the U.S. economy. Some of the arguments are presented on NAM’s web site and draw heavily on the arguments prepared by Joel Popkin and Company in June 2003 in a position report [Popkin, 2003] entitled Securing America’s Future: The Case for a Strong Manufacturing Base. In this paper, Popkin first develops a set of arguments that emphasize the importance of manufacturing to the U.S. economy. These arguments hold that manufacturing grows the economy by virtue of a large (2.43) multiplier effect, invents the future with its high expenditure on research and development, generates productivity increases, provides more rewarding employment and pays the taxes with an important contribution to growth and tax receipts. He then presents a set of critical challenges faced by U.S. manufacturing. These challenges include the loss of jobs, the rising cost of doing business in America, the loss of export potential, loss of investment and shortage of skilled workers. He concludes with a set of action items which call for leveling the international playing field, reducing the cost of doing business in the U.S. and promoting investment and innovation through taxation incentives. A summary of these NAM positions can be found on its web site and is reproduced here as Exhibit 2.1. The full Popkin paper is also available on the NAM website.
WASHINGTON, D.C., June 10, 2003 – While manufacturing has been the engine for healthy economic growth and good jobs, intense global competition and the rising cost of doing business in the U.S. threaten manufacturing’s capacity to maintain the nation’s economic strength and standard of living, according to a new study by economist Joel Popkin.

Manufacturing spawns more additional economic activity and related jobs than does any other economic sector,” stated Popkin, president of Joel Popkin and Company. The study, “Securing America’s Future: The Case for a Strong Manufacturing Base,” commissioned by the Council of Manufacturing Associations (CMA), contends that manufacturing is “the heart of an innovative process that powers the U.S. economy to global leadership” and that “America’s unprecedented wealth and world economic leadership are made possible by a critical mass of manufacturing within the geographic confines of the American common market.

Popkin shows how the unique linkages of manufacturing to the rest of the economy create more innovation, productivity and good jobs than any other sector of the economy,” said Jerry Jasinowski, president of the National Association of Manufacturers. “Popkin attributes America’s high standard of living to the manufacturing innovation process. Research and development stimulates investment in capital equipment and in workers, leads to new processes and products, generates spillovers that benefit other economic sectors, and ultimately leads to higher living standards.

However, America’s industrial leadership is being squeezed between unprecedented foreign competition based upon predatory trade practices that make it impossible to raise prices, and rising costs due to rising health care costs, soaring runaway litigation, and excessive regulation. The result is a dramatic decline in manufacturing cash flow that forces firms to cut back on R&D and capital investment, and to reduce employment. The U.S. manufacturing base is receding – and with it the all-important innovation process that is the seedbed of our industrial strength and competitive edge.

The loss of 2.3 million manufacturing jobs poses a real and present threat to the American middle class, “said Thomas Dammrich, president of the National Marine Manufacturers Association, and chairman of the CMA. “These are among the best paying jobs in our country, and almost all of them offer a full range of benefits, including health insurance. Every lost manufacturing job is a tragedy for someone’s family.

The greatest long-term impact of the erosion of U.S. manufacturing, according to the Popkin study, is on innovation. “U.S. manufacturing generates the greatest innovation process in the world by germinating and nurturing innovations from concepts through to full-fledged improvements in the products and processes that provide the basis for improved productivity, prosperity and a higher quality of life,” the study concludes. “But as U.S. manufacturers face serious challenges to their continuing existence, the critical mass necessary to maintain a dynamic innovation process is jeopardized.
If we want to maintain the R&D investment and innovation strength of the U.S. economy, we must require our competitors to compete on a level playing field, hold down the costs of doing business at home, and encourage R&D and investment,” said Jasinowski. “It is increasingly important that policy makers hike spending on R&D activities, that we enact a permanent R&D tax credit, and that the government provide incentives to increase the supply of scientists and engineers. The U.S. is facing a critical skills shortage in the near future as the current generation of manufacturing workers retires and few young people are coming into industry.”

“If the U.S. manufacturing base continues to shrink at the present rate and the critical mass is lost,” the Popkin study concluded, “the manufacturing innovation process will shift to other global centers. If this happens, a decline in U.S. living standards in the future is virtually assured.
Securing America’s Future: The Case for a Strong Manufacturing Base

Manufacturing Generates More Activity Per Dollar

The manufacturing process leads to increased economic activity in other sectors of the economy. For every $1 of goods produced, an additional $1.43 worth of additional economic activity is generated—more than any other economic sector.

“U.S. manufacturing is the heart of a significant process that generates economic growth and has produced the highest living standards in history. But today this complex process faces serious domestic and international challenges which, if not overcome, will lead to reduced economic growth and ultimately a decline in living standards for future generations of Americans.”


www.nam.org

National Association of Manufacturers

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Washington, DC 20004-1790
(202) 637-3000; fax (202) 637-3182; www.nam.org

Council of Manufacturing Associations
Manufacturing is the engine that drives American prosperity.

It's not just manufactured products that make Americans rich; it's the manufacturing process. This process starts with an idea... which leads to research and new innovations and inventions. That leads to new jobs and equipment... and increased productivity... and new products and processes. Prices fall and quality rises. Soon, other parts of the economy are benefiting. Ultimately, living standards rise.

But this extraordinary growth engine is losing steam. American manufacturers face greater challenges, both domestic and international, than ever before. Elected officials don't fully appreciate this threat— not just to U.S. employment and national security, but to our future prosperity.

Here's what you need to know and how you can help.

U.S. Manufacturing and Prosperity

Manufacturing provides enormous benefits for the entire U.S. economy. Manufacturing—

- Grows the Economy. Every $1 in manufactured goods generates an additional $1.43 worth of additional economic activity—more than any other economic sector.
- Invents the Future. Manufacturers are responsible for almost two-thirds of all private sector R&D, which ultimately benefits other manufacturing and non-manufacturing activities in the United States.
- Generates Productivity Increases. Manufacturing productivity gains are historically higher than those of any other economic sector. These gains enable Americans to do more with less, increase our ability to compete and facilitate higher wages for all employees.
- Provides More Rewarding Employment. Manufacturing salaries and benefits are among the highest in the private sector, and manufacturers are leaders in employee training.
- Pays the Taxes. Manufacturing has been an important contributor to economic growth and tax receipts at all levels of government, contributing one-third of all corporate taxes collected by state and local governments.
- Investments Going Elsewhere. U.S. manufacturing's share of capital investment and R&D expenditures, once a dominant feature of our nation's commitment to progress, are diminishing.
- A Shortage of Skilled Workers. Despite the loss of almost 3 million jobs, manufacturing is facing a potential shortfall of highly qualified employees with specific educational backgrounds and skills, especially those specific skills needed to produce manufactured goods.

The cost of doing business is rising dramatically, in large measure because of significant costs related to health care, litigation and regulation.

Manufacturing's Critical Challenges

While American manufacturing creates higher living standards, domestic and international challenges threaten its sustainability due to—

- Loss of Jobs. Since July 2000, manufacturing has lost almost 3 million jobs, many of which have relocated overseas. Output has shown little growth since the official end of the recession.
- Dramatically Rising Costs. The cost of doing business in the United States is rising dramatically, in large measure because of significant costs related to health care, litigation, regulation and energy. As a result, many U.S. manufacturers have shut down or moved production overseas.
- Loss of Export Potential. Manufacturing exports as a share of GDP have contracted since 1997, reflecting increased global competition, an overvalued dollar and difficult economic times overseas. Increased purchases of foreign-made goods have pushed the U.S. trade deficit to historic highs.

Demanding Action

No other sector generates prosperity for all Americans like manufacturing. Manufacturers and their employees must help raise awareness about manufacturing's importance and the danger of its demise. These include policies that—

- level the international playing field, such as ensuring that exchange rates are determined by markets and ensuring that countries such as China comply with international trade rules.
- reduce the cost of producing in the United States, including containing health-care costs, enacting legal reforms, ensuring plentiful and inexpensive energy supplies and reforming the regulatory system to ensure cost-benefit analysis.
- promote innovation and investment, through increased R&D support, a tax system that encourages research and development and incentives to attract scientists and engineers to this country.

What Can You Do?

- If you represent a company or non-profit organization, sign the Statement of Principles of the Coalition for the Future of Manufacturing available at www.nam.org/renewal. Signers become members of the coalition.
2.2 An Opinion from Peter Drucker
Peter Drucker is a writer, teacher and consultant who specializes in strategy and policy for business and social sector organizations. He is widely regarded as one of the most insightful observers of industrial organizations with an uncanny ability to see, foresee and synthesize important currents and developments. Panchak [Panchak, 1998] in an interview for IndustryWeek.com in 1998 asked his opinion about the importance of manufacturing in a world class economy and about the difference between a manufacturing and service company. The two questions and Drucker’s answers with his particular emphasis on the importance of mixing goods and services are reproduced here as Exhibit 2.2 so that the reader can evaluate Drucker’s own words. The full interview can be found at IndustryWeek.com’s website.

**Exhibit 2.2 – Interview with P. Drucker for IndustryWeek.com**

<table>
<thead>
<tr>
<th>IW:</th>
<th>Do you agree with IW's basic assumption that manufacturing is the most important part of any world-class economy?</th>
</tr>
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<tbody>
<tr>
<td>Drucker:</td>
<td>No and yes. If you define manufacturing as the production of things -- and even if you extend the traditional definition to embrace the entire system of bringing a product to market, as IW does -- I would strongly disagree. But I emphatically agree if you extend the definition to read &quot;the systematic process of production&quot; -- whether the end product is a &quot;thing&quot; turned out in a factory, an &quot;intangible&quot; such as software, or a &quot;service,&quot; such as a mutual-fund share.</td>
</tr>
</tbody>
</table>

Traditional manufacturing is likely to become less and less important to a developed country's health -- and actually in the emerging economies as well -- even though, as is almost certain, its volume will continue to go up, and go up fast (as it has in agriculture) while its contribution to employment and gross domestic product [GDP] shrinks. Systematic production, however, will steadily become more and more important and more and more central.

Let me explain: Manufacturing in the traditional definition, that is, making goods in a factory, has been shrinking worldwide for many years, and will continue to shrink. By the year 2015 or 2020, the volume of goods produced by traditional manufacturing worldwide will probably be at least twice what it is today. But in the U.S., employment in traditional manufacturing, already down to no more than one-sixth of the labor force, will have shrunk to no more than one-tenth. And the share of manufacturing in GDP, which is still around 15% or so, will have shrunk to 5% to 7%.

In that sense, traditional manufacturing in the U.S. is almost exactly where farming was around 1950. Farming still employed roughly one-fifth of the U.S. workforce, and produced something like one-tenth of GNP. Today, farming employs no more than 3% of the workforce and produces no more than some 2% to 4% of GDP. But farming production in the U.S. has increased almost sevenfold since 1950. . . .

If we redefine manufacturing as "the systematic process of production," manufacturing is indeed the most important part of any world-class economy. . . . The most important technical change in the last 30 or 40 years is that of the process of production, first developed in traditional manufacturing and now embracing more and more of the economy. It is becoming the process of production. It does not necessarily produce goods. But the new "goods" -- goods still usually classified as "services" -- increasingly are being organized on the principles of production that were first developed in manufacturing.

<table>
<thead>
<tr>
<th>IW:</th>
<th>Has the difference between a manufacturing company and a service company become so small as to be insignificant? Or do the two types of companies still differ significantly? Please explain.</th>
</tr>
</thead>
</table>
Drucker: Again, the answer is both yes and no. The difference is still tremendous. And the difference is not in the process of production but in the basic theory behind it -- and that may be as important as the system of production, or even more important. What we call a "service company" does not, as a rule, see production as the process that adds value. It basically starts out with customers and service. The traditional manufacturing company still looks on the physical process of production as its center. But this will have to change. Increasingly traditional manufacturing companies will see the process of production as the means to an end rather than as the end itself. . . .

The service companies -- or most of them -- are changing so fast that the distinction between manufacturing company and service company is becoming totally meaningless. Producing software -- we still classify it as a service industry, but it is a production industry. And the more it is being organized on a systematic process of production, the more productive and the more successful it is. Handling thousands, if not millions, of credit cards -- we call it a service industry. But it is clearly a production process. So, of course, is check clearing. So is the handling of insurance claims. . .

Altogether, there are no more service industries in the traditional sense. There are only production industries. And to the extent that they apply principles of production that traditionally were considered manufacturing, they become competitive and successful.

IW: Please comment on how the new manufacturing has affected the traditional manufacturing industries: automobile, steel, food, pharmaceutical.

Drucker: The new manufacturing -- maybe I should call it the switch from manufacturing to production -- is rapidly transforming the traditional industries. In steel, which is perhaps the most representative industry of the peak age of traditional industrialization, the shift is from the now-antiquated integrated steel mill to the minimill, which is basically a shift from production based on machinery to production based on information.

Let me explain: What characterizes the minimill is the restructuring of the entire process around information. This, then, made possible (a) total automation -- the specs of the order program the entire process; and (b) the cut in the number of people employed by some 80% or more and their conversion from manual workers putting to work mostly brawn (and a little skill) into knowledge workers running an automated process through its controls.

The pharmaceutical industry learned that long ago. It has become a systems-based production industry in which the starting point is not making the stuff but serving the health service.

And perhaps the greatest change has been in the traditional industries that serve the infrastructure, whether they are the makers of heavy earthmoving equipment such as Caterpillar, the makers of locomotives such as GE, the makers of container ships, and so on. They have been restructured as systems companies in which the starting point is not making goods but service to enable the customer to get the fullest benefit from the goods.

The automobile industry has not yet learned that; it will have to or it will become a declining and money-losing industry. The automobile industry may be today's most antiquated industry precisely because until very recently it could operate the way it had been operating since William Durant [formed] General Motors in 1908 and first designed the modern automobile company. That no longer works -- and you can be reasonably sure that in the next 10 to 15 years the automobile industry will change more drastically than it has in the last 70 or 80 years. It will become an industry that focuses on service -- marketing the car, servicing the car, servicing and selling the used car -- rather than on the traditional profit center, which is making the new car. . . .
2.3 Comments from George Akerloff, Nobel Laureate in Economics

The comments of Professor George Akerloff (University of California at Berkeley) on the future of manufacturing were reported as part of an editorial column by Louis Uchitelle [Uchitelle, 2003] in the New York Times, August 17, 2003. In his column, Uchitelle laments the loss of manufacturing jobs and resulting diminishing U.S. power that would follow and reports that many economists believe that the marketplace will ultimately respond with a solution to this problem. He also states that economists believe that the large manufactured goods deficit of the U.S. is made possible by loans from abroad. As the U.S. debt increases, a potential loss of confidence in the U.S. as an investment heaven will ultimately cause the value of the dollar to fall significantly. He then continues:

That will make imported manufactured goods prohibitively expensive, while merchandise exported from the United States will fall in price, when sold in yens or euros. Responding to this price incentive, manufacturers will rebuild in America, says George A. Akerloff, a Nobel laureate who is an economist at the University of California at Berkeley. “Manufacturing has to come back,” he said. No other sector is likely to be as responsive to dollar devaluation. For Mr. Akerloff, retooling is the easy part. Other experts disagree. Too many products are no longer manufactured here, they argue, and the skill to make them has disappeared. Resurrecting that skill is difficult. Dollar devaluation does not easily overcome that barrier. Nor does it easily woo back American companies that have invested huge sums in large, modern facilities abroad. Getting them to abandon those facilities and rebuild in the United States might require an outsized 60 percent devaluation of the dollar as an incentive, says Daniel Luria, an economist at the Michigan Manufacturing Technology Center in Plymouth. The fallout would be painful. The Nissan Maxima, made in Japan, that I bought in 2000 for $25,000 would cost at least $40,000 to replace. That’s over my head.”

2.4 The Position of Bruce Bartlett from the National Center for Policy Analysis

For B. Bartlett [Bartlett, 2003], Senior Fellow with the National Center for Policy Analysis, the state of U.S. manufacturing is very healthy and doing very well in every sector except in the number of people it employs. He points out that:

- Although manufacturing employment is down 16% in three years, much of the change in industrial employment is an effect of changes in the classification of jobs and companies outsourcing of “non manufacturing” jobs within large manufacturing organizations.
- In contrast to the employment picture, total goods production (including items like mining, agriculture in addition to manufacturing) has increased substantially as a % share of GDP (37% in the 1960’s, 39.4% in 2000). Manufacturing share of GDP has also grown (16.2% of GDP in 2001 versus 16% in 1991, inflation adjusted).
- U.S. real GDP per employed person is the highest in the world according to Bureau of Labor Statistics (2002) and that is what really counts (Figure 2.1).
- Protectionism is not a solution to these perceived problems.
2.5 The Position of Gregory Tassey, Senior Economist at NIST
Tassey [Tassey, 2002] uses a planning report entitled “R&D and Long Term Competitiveness: Manufacturing’s Central Role in a Knowledge-Based Economy” to argue strongly on behalf of a renewed R&D effort to build a “deep and diverse technology-based manufacturing sector” and produce a broad range of innovative products and services. Of particular interest to the debate on the importance of manufacturing for the future, Tassey contends that a significant amount of research supports the view that “hardware and software components are most efficiently supplied to services by a manufacturing sector that is geographically close and institutionally integrated with the service applications.” The view counters the oft repeated argument that the loss of manufacturing jobs is inconsequential as it will be replaced by service sector jobs. Tassey assesses the state of U.S. manufacturing as being about one third high technology with the remainder mostly purchasing their technology from the high technology sector. He considers this latter segment of the industry as particularly vulnerable to foreign competition which is now also in a position to imitate the acquisition and absorption of technology while in some cases enjoying a considerable advantage on the price of labor. According to Tassey, the prospects of this segment of the industry are not very good.

2.6 Comments and advice from Bruce Braker, President-Tooling and Manufacturing Association (TMA)
Braker’s [Braker, 2003] comments were particularly interesting with respect to the loud chorus in the labor movement which holds unfair foreign competition responsible for the loss of manufacturing jobs and demands a “leveling of the playing field.” Here are some of his words about this issue:

Some manufacturers say, “We can’t compete until we have a level playing field!” TMA respects the lobbying efforts aimed at leveling the playing field and the association participates heavily in those efforts. We should continue to demand that level playing field, but we can’t afford to plan and act as though we expect meaningful results from
those demands anytime soon-if ever. Don’t depend on anyone’s lobbying efforts to level the playing field. Don’t depend on the next election to level the playing field. Don’t depend on your trade association to level the playing field. Don’t depend on a level playing field-get in shape to run uphill. If it flattens some that’s great, but don’t depend on it.

In an interview with James Lorincz [Lorincz, 2003] of Tooling and Production, Braker notes that the market for first, second, third and fourth tier subcontractors in precision contract manufacturing (PCM) is still huge: 214 sectors served by the PCM industry are reported to have accounted for $1.82 trillion (1997 dollars) in business in 2001. Braker’s advice is that “there is business to be had” and he follows with a 20-point prescription for survival as shown below:

1. Target companies committed to manufacturing in the U.S.
2. Export or sell to customers who export
3. Hire skilled sales people or reps
4. Sell to a broad, diversified base
5. Sell to customers who pay their bills
6. Develop unique market niches
7. Build networks with subcontractors and partners to joint bid
8. Provide diversified services
9. Add engineering, design, and consulting value to tooling and parts
10. Be consumer focused
11. Plan and implement plans
12. Hire great people with the right skills
13. Prune marginal people with the wrong skills
14. Educate, train, delegate, inspire and lead
15. Have a global perspective
16. Selectively source worldwide
17. Invest in automation and technology
18. Produce better, faster, cheaper
19. Have a clean balance sheet
20. Keep the faith-stay in the game

2.7 The Thoughts of Representative Donald Manzullo (R-IL), Chairman of the House Small Business Committee
Chairman Manzullo’s [Manzullo, 2004] concern is with the problems faced by small manufacturers which in his view “are essential to prosperity and community and create hope and economic opportunity.” He elaborates on his position with a 10 point summary of critical issues shown below as Exhibit 2.3, as it appeared on the website of North American Die Casting (www.diecasting.org/government/top10.htm).
### Exhibit 2.3 – Chairman Manzullo’s Top Ten List of Problems Facing Small Manufacturers

<table>
<thead>
<tr>
<th>Problem</th>
<th>Details</th>
</tr>
</thead>
</table>
| **1. Washington” does not understand the importance of manufacturing** | • Some of the rhetoric we hear in Washington includes: “Everyone wants a white-collar job” and “Manufacturing is ‘only’ one small segment of our economy.”  
• Government does not understand the “multiplier effect” of manufacturing — $1 million in manufacturing sales equals eight manufacturing jobs plus six service jobs as compared to $1 million in service sector sales equals 3.5 service jobs. *We need to educate members of Congress about the current state of small- and medium-sized manufacturers.* |
| **2. Surging cost of all insurance (including health care)**            | • Small business premiums are soaring by 20 percent to 40 percent.  
• The percentage of small businesses offering health care benefits is slumping from 67 percent in 2000 to 61 percent in 2002.  
• Sixty percent of the nation’s 43 million uninsured are small business owners, their employees and their families. |
| **3. Regulations continue to burden struggling businesses:**           | • Complying with government regulations costs businesses about $843 billion per year ($8,164 for a family of four) or eight percent of GDP.  
• The annual regulatory burden is 60 percent higher for small firms with fewer than 20 employees compared to large firms with more than 500 employees. *We must fight government regulation with the Regulatory Flexibilities Act requiring agencies to analyze the economic impact on small business before a regulation is final. Agencies must follow the law.* |
| **4. U.S. local, state and federal tax burden:**                      | • The United States has one of the highest corporate tax rates — national and state taxes — at 40 percent, compared with other developed nations which average 31 percent.  
• Companies moving outside of the United States to avoid taxes are wrong but our tax system is flawed. *The Job Protection Act of 2003 would lower corporate taxes for domestic manufacturers by 10 percent.* |
| **5. Lack of access to capital:**                                      | • Fees are too high on Small Business Administration (SBA) loan guarantee programs, making the programs unattractive for most small manufacturer borrowers.  
• Banks are reluctant to lend to small manufacturers in the Midwest. *Increase access for small businesses to SBA guaranteed lending programs; raise SBA loan limits for manufacturers; and support the BRIDGE Act (tax deferral initiative) to help small businesses’ capital needs.* |
| **6. Overvalued U.S. dollar.**                                         | • Foreign governments routinely interfere with currency markets to prevent their currencies from appreciating against the dollar. |
| **7. New steel tariffs and corresponding spikes in domestic prices:**   | • Small manufacturers have seen domestic steel prices rise up to 80 percent.  
• U.S. sales are being lost to foreign companies purchasing steel at world prices.  
• High steel prices have made manufacturers uncompetitive.  
• Big steel producers are breaking existing contracts to |
arbitrarily raise prices.

- The International Trade Commission is studying the impact tariffs are having on steel users. The administration has the opportunity to end steel tariffs at the midterm review period in September 2003.

### 8. Federal procurement is working against our manufacturers:
- The federal government’s $200 billion annual purchase of goods and services rarely reaches the 23 percent goal for small businesses.
- The federal government is using taxpayer dollars to import goods as opposed to sourcing from domestic manufacturers.
- The U.S. must continuously examine Pentagon procurement practices (Army berets/Joint Strike Fighter/titanium) to keep production in the U.S. while fighting unsound contract bundling and consolidation. The House-passed Defense Authorization Bill raises buy-American content requirements to 65 percent from 50 percent and mandates defense contracts greater than $5 million must use American made machine tools, dies and industrial molds.

### 9. Export controls and unilateral trade sanctions:
- Export controls and trade sanctions cost $20 billion to $40 billion in lost exports per year or roughly 400,000 jobs.
- Export controls place severe limitations on the ability of high-tech manufacturers and machine tool builders to sell “dual use products” to countries not allied with the United States. Other nations do not have these limitations and take away sales from American manufacturers.
- The State Department is using Visa immigration policy to restrict foreign visits of potential buyers of U.S. products.
- Export policies cause U.S. businesses to be unreliable suppliers, and allies use export policies against our businesses. Because of counter-productive export controls, the U.S. lost the five-axis machine tool market to China in 1997.

### 10. Foreign trade barriers:
- Trade barriers currently cost U.S. businesses $200 billion annually, according to a University of Michigan study.
- The United States is one of the world’s most open economies, but domestic producers struggle in an uncertain international tariff environment.
- Level the playing field through the use of anti-dumping and countervailing duty trade laws and the Byrd amendment (higher tariffs go to injured companies, not the U.S. Treasury).

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### 3. GLOBAL ENVIRONMENT GROUP

This section of the document reports on the results of a prospective evaluation carried out to elicit a subset of dominant drivers that are now exerting or are likely to exert considerable influence on the current or the future state of manufacturing. An exhaustive evaluation of the potential drivers would have been difficult given the time constraints of the project. The project therefore settled on four key drivers not under consideration by any of the other NIST-funded projects (Innovation, Global Strategies and Supply Chains), and which we perceive to become increasingly important on the global
manufacturing scene. These include globalization, ecological awareness, demographics and technology. They will be treated in turn.

3.1 GLOBALIZATION

W.K. Tabb [Tabb, 2003] defines globalization as “A comprehensive term for the emergence of a global society in which economic, political, environmental, and cultural events in one part of the world quickly come to have significance for people in other parts of the world. Globalization is the result of advances in communication, transportation, and information technologies. The most dramatic evidence of globalization is the increase in trade and the movement of capital.”

Globalization is often cited as a factor that has already exerted considerable influence on the manufacturing activities of this country and as a driver that will continue to affect the future of manufacturing. It is perhaps informative to first get an idea of the advances in communication, transportation and information technologies that have facilitated globalization and then to examine examples of how economic, political and environmental events in one part of the world can affect manufacturing activities in this country.

Holt [Holt, 1999] tabulates International Monetary Fund (IMF) data (see Figure 3.1.1) to show the dramatic changes in the cost of transportation and communication that have facilitated worldwide exchanges of goods, people and ideas. World usage of the Internet continues to grow exponentially (see Figure 3.1.2) and in dramatically less time (see Figure 3.1.3) than the previous technologies such as radio, personal computer or television. The power of this new information technology medium is fueled by sustained improvements in the computing speed (Figure 3.1.4 shows what US$1000 will buy in computations/sec), the price of storage (Figure 3.1.5) and fiber bandwidth evolution (Figure 3.1.6) [Feldman, 2003]. Computer-based design, manufacturing and management activities have been greatly facilitated by hardware and software developments. Products can now be developed and analyzed at one location and sent electronically across the globe to be manufactured close to market or to take advantage of more favorable manufacturing conditions.
The graph on telephone costs does not reflect the global trend which has remained regulated in many parts of the world.

*Figure 3.1.1 – Changes in Transportation and Communication Costs
(Source: IMF, Benjamin Holt, July 1999, Global Policy Forum)*
Figure 3.1.2 – Internet Usage  
(Source: Nua Internet Surveys, Graph by Tom Hale, July 2003, Global Policy Forum)

Figure 3.1.3 – Time for Growth of Communication  
(Source: Economist, Graph by Benjamin Holt, July 1999, Global Policy Forum)
Figure 3.1.4 – Improvements in Computing Speed (Source: Feldman, S., 2003, IBM)

Figure 3.1.5 – Improvements in Price of Storage (Source: Feldman, S., 2003, IBM)
A number of political and economic events over the last decades have played a significant role in the effect of globalization on the state of manufacturing in this country and abroad. While an exhaustive review of these events is beyond the scope of this study, three specific events have been selected for a brief review to highlight their effect on the current state and future of manufacturing activities. These include the dramatic increase in trade agreements and trade liberalization, the emergence of the European Union as an influential world player and the rise of China as a hub for labor-intensive manufacturing.

Tom Hale [Hale, 2003] uses World Trade Organization (WTO) data to plot the growing number of Regional Trade Agreements (RTAs) around the world and the graph (Figure 3.1.7) shows a step increase and linear growth starting around 1972 followed by an explosive increase from 1992 to 2002. When this graph is compared to that of the evolution of total value of world exports (Figure 3.1.8), the high correlation between the increase in the number of regional trade agreements and the exponential increase in total value of world exports is clearly evident. Trade liberalization has allowed multinational corporations, transnational corporations and even small national companies to move manufacturing production to locations where they can take advantage of one or more factors such as:

- Low wages and other compensation obligations such as pensions and health care.
- Financing, subsidies and loan guaranties offered by foreign governments.
• Workforce education and infrastructure support.
• Lower taxation and regulatory constraints.
• Closeness to the market where the goods are sold
• Lower exposure to shifting exchange rates
• Easing of trade frictions.

Figure 3.1.7 – Number of Regional Trade Agreements
(Source: WTO, Graph by Tom Hale, July 2003, Global Policy Forum)
Nearly 10 years after the North American Free Trade Agreement (NAFTA) was passed, U.S. and other foreign firms that shifted manufacturing production to Mexico were responsible for creating some 1.3 million jobs which propelled that country to supplant Japan as the number two exporter to the U.S. behind Canada. Mexico in turn is now hemorrhaging manufacturing jobs to China as U.S. (e.g., toy maker Hasbro) and foreign manufacturers such as Sanyo (televisions) and Philips (PC monitors) are closing shop and moving to China where labor rates are reported to be as low as $0.72/hr or one quarter of the average Mexican rate [Sneider, 2003].

The phenomenon of the manufacturing job flight is not limited to America. Toyota City, the city that Toyota developed to supports its relentless drive to the top of the auto manufacturing scale is facing the same flight of manufacturing jobs experienced by U.S. cities. Toyota has become a leading proponent of “localizing” its production to build automobiles closer to the markets where they are sold. The company has spent some $13 billion over the last two decades building factories in North America alone and helped develop numerous local suppliers to support and feed these factories [Belson, 2003]. Other leading auto manufacturers such as Honda, Nissan, Mercedes and BMW also set up substantial manufacturing and assembly operations in North America, away from their national homelands.
Lander [Lander, 2003] reports that having been at the heart of the East German semiconductor industry during communist times, the small German state of Saxony has now managed to use financial incentives ($1.5 billion worth of subsidies, financing and loan guarantees), a substantial educational infrastructure (20 colleges, 4 universities, and 38 research institutes), an educated workforce (17% of the workforce has a college education) and lack of export restrictions to lure Advanced Micro Devices (AMD) to join a growing number of high tech microelectronic manufacturers in Saxony, and build a $2.4 billion advanced microprocessor manufacturing plant in Dresden. This is the second plant AMD is building in Dresden and no U.S. city could match the financial advantages offered by Saxony to a company reported to have a weak balance sheet and one tenth the size of Intel. European rules however prohibit the kind of incentives offered by Saxony after 2006 and the next AMD plant may very well not be in Saxony but in one of the new members of the European Union that will still be entitled to offer such subsidies.

This dynamic allocation and re-allocation of manufacturing production to locations that provide a competitive advantage to the firm appears to be a business model that will continue in the future in spite of labor and political calls for protection of local jobs, and the problem this model poses for low skilled workers in the developed countries. Goldman Sachs estimates that of the 2.7 million U.S. manufacturing jobs lost in the last three years, one million of these jobs relocated abroad. Forrester Research predicts that this practice, which is already spreading to white collar jobs, will move some 3 million white collar jobs abroad in the next 15 years.

The flight of manufacturing jobs abroad, however, is not always a winning proposition. Some of the drawbacks that have been reported by U.S. manufacturers include cultural differences, shipping and supply chain problems as well as lack of specialized skills. Hagenbauh [Hagenbaugh, 2003] reports the following experiences related by a number of U.S. manufacturing firms:

- A U.S. furniture importer has met considerable resistance trying to have his foreign supplier “distress” furniture for the U.S. market. The workers did not understand the value of making a brand new piece of furniture look much older.
- Customer resistance to overseas call centers has pushed Dell to review its policy of assigning some important corporate clients to overseas call centers.
- Air Products and Chemicals of Bethlehem, PA is keeping its natural gas machinery manufacturing plant in the U.S. because it estimates that the specialized technology and the skilled workforce it has built over the years are simply not easily transferable abroad.
- Mass customized upholstered furniture (leather and textiles) is still flourishing in the U.S. because Chinese factories cannot possibly match the customization and delivery times that most customers demand. It takes about 6 weeks after production to ship from China. Additional delays and regulations related to homeland security will probably increase the regulatory burden and shipping time.
- Lower overseas manufacturing costs are often outweighed by the length of the supply chain (sometimes as long as 12,000 miles) and increased logistics and inventory costs associated with such a supply line.
The second globalization event worthy of consideration is the emergence of the European Union as a substantial economic market with economic and regulatory policies that can influence manufacturing enterprises throughout the world. The recent expansion of this economic bloc from 15 to 25 nations brings the total population to 455 million and a GDP of €9.6 trillion. This is now a substantial market with a total population far in excess of that of the U.S. and a GDP comparable to that of the U.S. Its influence on manufacturing activities is expected to be felt through regulatory policies and governmental industrial policies. An example of the effect of EU regulatory power on manufacturing can be seen in the effect of the newly adopted (2003) directive on the Restriction of Hazardous Substances (ROHS) and Waste from Electrical and Electronic Equipment (WEEE) on worldwide manufacturing practice. One of the many restrictions contained in this directive is the phasing out by July 2006 of lead from electrical and electronic equipment. The regulation is sending large brand name owners as well as small suppliers and manufacturers worldwide, to scramble for a lead-free solder alternative, and product/process redesign away from the eutectic tin-lead (Sn-Pb) alloy used for decades. This situation is examined in a little more detail in the section on ecological awareness.

The second way in which the EU can exert its influence on manufacturing activities is through the coordinated industrial policy of some of its members. The model that readily comes to mind is of course that of aerospace and the Boeing/Airbus rivalry. Airbus is a pure creation by France, Germany and Spain of an aerospace giant that now competes on a global scale with Boeing and has grabbed a bigger share of the world aerospace market from its U.S. competitor (see Figure 3.1.9). The Airbus creation was both a political and economic decision engineered to maintain European presence in a critical technological sector and to preserve and expand valuable manufacturing jobs.

Note that while the Airbus market share came at the expense of Boeing, Airbus business with U.S. industry reached some $5.5 billions in 2002, employing about 120,000 US. Workers in more than 40 states. (Airbus North America website) There is reason to believe that the Airbus success model is pushing European industrial leaders to duplicate it in other areas such as the pharmaceutical industry and the shipbuilding industry. Intense negotiations for the consolidation of some fragmented pieces of the European pharmaceutical industry have been reported in the first quarter of 2004 with the deliberate French-German aim to create one or two European “champions” that can rival U.S. pharmaceutical industrial giants. Talk is also leaking out about potential consolidation in the shipbuilding industry to create a “seabus” giant, modeled after Airbus that would
compete with the Asian shipbuilding manufacturing giants. High speed mass transportation systems, and particularly the manufacture and worldwide marketing of high speed trains is also a possibility.

The third aspect of globalization worthy of attention is of course the rise of China as a major global manufacturing hub for labor intensive products. Its purported influence on the loss of manufacturing jobs in this country has been widely discussed in the media by way of anecdotal stories but N.R. Lardy [Lardy, 2003], a senior fellow at the Institute of International Economics argues that the future effect of China on the U.S. is hard to judge, as it may present both a threat and an opportunity.

Lardy traces the origin of the rise of China as a manufacturing export power to the economic liberalization moves that established the joint venture law in 1979 followed by the establishment in 1980 of special economic zones on the southeast coast. Contracted foreign direct investment (FDI) which averaged about $3 billion/year in the 1980’s exploded to $111 billion in 1993 (see Figure 3.1.10) as foreign firms rushed to China to take advantage of a vast labor supply at wages averaging one fourth (see Figure 3.1.12) of those that fueled the Mexican manufacturing boom. China’s FDI inflows surpassed those of the U.S. in 2002, making China the world’s leading destination for foreign funds. Moreover, in 2002, more than two-third of China’s incoming FDI flowed into manufacturing investments, and particularly low technology, labor intensive manufacturing as more investors tended to resist transferring high value-added operations to China. The largest proportion by far of FDI contracted or utilized continues to come from Asian countries such as Hong Kong, Taiwan, and Korea and not from the U.S. as the conventional wisdom believes (see Figure 3.1.11). Lardy argues that China essentially

Figure 3.1.10 – A Snapshot of Foreign Direct Investment in China (FDI)
(Source: The U.S.-China Business Council)
displaced these three countries as the major exporter of labor intensive manufactured goods such as footwear, toys, sporting goods and games to the U.S. As wages in Hong Kong, Taiwan and Korea rose, labor intensive manufacturing became less competitive causing manufacturers in these countries to move to China and use it as a new export platform to the U.S. (Figure 3.1.12). Lardy also argues that the same process repeated itself for electronic consumer goods such as radios, TVs, VCRs and DVDs and is now moving to include information technology products such as PCs, notebooks, monitors and PDAs. He estimates the IT industry at some $300 billion, a large portion of which has resided in Asia for a long time and is now migrating from places like Taiwan to mainland China. The net result is that U.S. imports of goods from China in 2002 amounted to $125 billion, while exports of aircraft, integrated circuits, chemical
fertilizers, software and other goods added up to a mere $22 billion, leaving a trade gap in manufactured goods of $103 billion (see Figure 3.1.13). Most of the conventional wisdom believes that both U.S. and foreign firms will continue to use China as a hub for labor intensive manufacturing in spite of the loss of manufacturing jobs in the industrialized world. Lardy also points out that 3/5 of the output produced by foreign firms in China is sold in that market and that China continues to hold the promise of the fastest growing market for U.S. companies.

The influence of China on the flight of manufacturing jobs in the West is almost always associated with low technology, high labor content manufacturing and assembly. However, a look at recent press releases and investment activities by large Chinese state affiliated firms and foreign multinational companies shows that China’s aim goes far beyond the low technology labor intensive manufacturing.

China has a small (relative to its large population) but first class engineering and science educational system. Moreover, its nationals have a large presence in science and engineering doctoral programs on U.S. campuses. These highly trained students are expected to return to their country in larger numbers because of the opportunities now available in China.

Figure 3.1.13 – The U.S. Manufactured Goods Trade Picture in 2002
(Source: Global Manufacturing Series - www.itcc-tma.org/mfgdata.html)

Figure 3.1.14 – China’s Car Production
(Source: CEIC Data Company)
China, the country that over the years epitomized the role of the bicycle for transportation, aims to become a world player in car manufacturing (Figure 3.1.14). Their exports to the U.S. at the present time consist mainly of replacement parts and quality is still poor. However, Bernd Leissner, the President of Volkswagen Asia-Pacific estimates that the 18% production cost advantage that the typical western factory has over its Chinese counterpart will disappear by 2006. GM has just announced that it will be spending $3 billion over the next 3 years to displace Volkswagen as the number 1 car maker in China. New steel mills and new assembly plants with the latest automation equipment and part factories are opening at a high rate and China is expected, in few years, to be able to build parts and cars cheaper than anyone in the world. J.D. Power and Associates forecast that China will surpass Germany as the world’s number three carmaker in about 4 years. So far, Honda is the only carmaker with explicit plans to export Chinese assembled cars to the industrialized world. NEC and China’s largest homegrown electronics company, the SVA Group (a state owned company) plan to pour $1.1 billion into building China’s first plant dedicated to making liquid crystal displays (LCD) in Shanghai. Likewise, Beijing Orient Electronics Group Co. Ltd (another major state owned electronics company) is investing $1.2 billion to produce fifth-generation TFT-LCD lines near Beijing. Should these ventures become successful in the next few years, China will become part of a handful of countries that have mastered this reportedly very difficult manufacturing technology.

Chinese state delegations have been reported in the news to have visited India’s software hub to study its structure with the intention of launching their own software industry.

Lardy points out that in spite of the phenomenal strides achieved by the Chinese economy, their future remains uncertain as the leadership may yet face a number of challenges such as:

- The ability to sustain economic growth and improve living standards.
- Compliance with WTO requirements to cut tariffs; elimination of non-tariff barriers will lead to high unemployment and social unrest.
- Rising income inequality which may also lead to social unrest.
- A looming crisis in the banking system.

The industrial world has had a small glimpse of the consequences a small disruption in the Chinese system can cause to the supply lines during last year’s SARS epidemic. U.S.-based manufacturers who have entered into supply relationships with China must weigh the impact of future disruptions. Unlike the old Soviet Union and most of its satellites, China has yet to have its political revolution.

While China has dominated the manufacturing news discussions in this country and around the world, another population giant, India, with some 1.05 billion people, has made significant strides in the IT, software, and service industry sectors. Its potential as a future manufacturing export hub however is not clear. The Indian manufacturing sector is reported to contribute about ¼ of the total GDP (IndiaOneStop.com) (estimated GDP in 2004 is around $648 billion) and employ some 30% of the non-agricultural workforce in
industrial sectors including textiles, processed food, steel, machinery, transportation equipment, cement, chemicals, mining, petroleum and software (see Tables 3.1.1-3.1.2).

<table>
<thead>
<tr>
<th>Country</th>
<th>Relative Labor Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>100</td>
</tr>
<tr>
<td>India</td>
<td>164</td>
</tr>
<tr>
<td>Indonesia</td>
<td>138</td>
</tr>
<tr>
<td>S.Korea</td>
<td>1,474</td>
</tr>
<tr>
<td>Malaysia</td>
<td>469</td>
</tr>
<tr>
<td>Philippines</td>
<td>336</td>
</tr>
<tr>
<td>Singapore</td>
<td>2,924</td>
</tr>
<tr>
<td>Thailand</td>
<td>371</td>
</tr>
</tbody>
</table>

Table 3.1.1 – Relative Labor Cost (China = 100)
(Source: Annual Survey of Industries, U.S. Census Bureau)

<table>
<thead>
<tr>
<th>Major Products</th>
<th>($ billions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemicals</td>
<td>31.9</td>
</tr>
<tr>
<td>Food &amp; Beverage</td>
<td>30.3</td>
</tr>
<tr>
<td>Petroleum Products</td>
<td>22.4</td>
</tr>
<tr>
<td>Basic Metals</td>
<td>20.6</td>
</tr>
<tr>
<td>Textiles</td>
<td>16.8</td>
</tr>
<tr>
<td>Electrical Machinery</td>
<td>6.4</td>
</tr>
<tr>
<td>Transportation Equipment</td>
<td>5.0</td>
</tr>
<tr>
<td>Fabricated Metal Products</td>
<td>4.5</td>
</tr>
<tr>
<td>Communication Equipment</td>
<td>4.5</td>
</tr>
<tr>
<td>Furniture</td>
<td>3.6</td>
</tr>
<tr>
<td>Machinery &amp; Equipment</td>
<td>9.5</td>
</tr>
<tr>
<td>Motor Vehicles</td>
<td>9.5</td>
</tr>
<tr>
<td>Rubber &amp; Plastics</td>
<td>7.1</td>
</tr>
</tbody>
</table>

Table 3.1.2 – Major Products in India
(Source: Annual Survey of Industries 2001-2002, U.S. Census Bureau)

India’s economic performance however is no match for that of its Chinese neighbor. In 2002 for example, China exported eight times more goods, received twelve times more foreign investment and grew as twice as fast. In spite of this disparity, some observers still feel that India’s long term prospects are better than those of China. Drucker, in particular, in an interview with Fortune, advances the following arguments on behalf of India’s advantage:
• India has a better educational system than China, a greater talent pool and a large segment of the population (some estimates put it at 150 million people) that is fluent in English. India’s seven Indian Institutes of Technology (IITs) offer some of the most demanding and selective engineering programs in the world and about 25,000 IIT graduates are estimated to be working in the U.S. In India, the low cost talent pool produced by the IITs is bound to attract foreign investment (particularly U.S.) in R&D and manufacturing.

• India has already succeeded in absorbing excess rural population into its cities while China’s likelihood of doing so without social strife appears to be low.

• China’s large sector of obsolete stale planned and run factories contribute a social and economic time bomb for the country,

• India is the most populous democratic system in the world; China is still ruled by an autocratic one party system

Working against India’s progress, however, are complicated bureaucratic procedures which hamper foreign investment as well as a weak infrastructure (roads, bridges, ports) and high oil prices which do not encourage exports.

![Graph](3.1.15 – India-U.S. Trade in Services (Source: U.S. International Trade Commission))

3.2 ECOLOGICAL AWARENESS

Ecology is the branch of biology that deals with the complex of relations between living organisms and their environment. The Ecological Society of America predicts that the world, its people, governments, and industries will require increasingly sophisticated ecological knowledge in order to ameliorate a rapidly deteriorating state of the environment, utilize the earth’s resources, and enhance its capacity to sustain the needs of a rapidly growing world population. The manufacturing industry is a major consumer of
the Earth’s resources and a producer of substances and products that interact with the environment. The history of manufacturing interaction with the environment is marked by some spectacular market failures. The effects of mercury poisoning from industrial dumping in Japan’s Minamata Bay some 50 years ago are still haunting Japanese industry. Today, the Japanese government is still under pressure to boost victim compensation as medicine and science discover additional effects of the contamination.

Some 25 years after its leaking poisons forced families to flee, America’s most notorious toxic dump, the Love Canal development [Reuters, 2003] is finally welcoming families back. The cleanup cost alone paid by the Occidental Chemical Corporation was over $200 million. Even though the first study showing major health and safety problems associated with polychlorinated biphenyls (PCBs) was done in 1936, the General Electric Corporation started to use PCBs in 1947 in the manufacture of electrical capacitors at its Ft. Edward plant on the eastern shore of the Hudson River [Clearwater News & Bulletins]. Responsibility for the cleanup costs is still being fought over in the courts today. Likewise, the asbestos manufacturing industry sold billions of dollars worth of asbestos products even though evidence that this substance caused serious respiratory diseases in humans was preponderant for years before the industry took off in the 1930s. The subsequent litigation and compensatory awards are now legendary in the annals of product liability.

These and similar events over the years have spawned a number of regulatory and legislative actions that impact manufacturing activities. Some of these environmental regulations in the U.S. include the Clean Air Act, the Clean Water Act, and the Resource Conservation and Recovery Act. These regulatory policies govern the way manufacturers handle and dispose of manufacturing products and by-products discharged into the air, water, and soil. Many manufacturers argue that the manufacturing sector is now over-regulated, imposing a heavy and disproportionate burden on the industry. Popkin [Popkin, 2003] states that in 1999, the direct cost to the manufacturing sector for new pollution abatement equipment was $44 billion, or 76% of all such expenditures by U.S. industry. In addition, Popkin also quotes Census Bureau statistics showing that manufacturers incurred $10.2 billion in operating costs for on-going abatement activities, or 87% of all amounts spent by all industries. The public sector, however, views these regulations as necessary for the protection of the public and the environment with the added advantage of forcing innovation that leads to efficient use of resources and, hence, the well being of the firm.

Even though PCBs, asbestos, and other harmful substances are no longer used in manufactured products today, past market failures have sensitized a substantial proportion of consumers and public officials to be on the lookout for technological innovations that may repeat some of the tragic failures of the past. Virus resistant crops developed with some of the latest genetic engineering techniques are being shelved by companies such as Seminis and Monsanto because of the high costs of obtaining regulatory approval and perceived consumer resistance. Plans to introduce the world’s first genetically modified wheat were also dropped this year by Monsanto, the world’s biotechnology leader, because American and Canadian farmers feared that European and Japanese consumers would then shun both genetically and non-genetically modified
wheat from North America [Pollack, 2004]. In this business model, the manufacturer and the farmer see profit and productivity increases, but the consumer, the ultimate recipient of the goods, sees a potential health and environmental threat. Alarm bells were also set off in the nanotechnology field when this year Dr. E. Oberdörster, an environmental toxicologist at Southern Methodist University in Dallas, and other researchers reported that buckyballs, a most promising nanotechnology material, can cause severe brain damage in fish and alter the behavior of liver cells in juvenile fish. DuPont researchers also acknowledged that the company is beginning to address numerous fundamental questions about the toxicity of these nanoparticles [Feder, 2004].

The difference between today’s stories about emerging manufacturing advances and the manufacturing failures of the past is that increased ecological awareness, regulatory supervision, and the prospect of costly litigation are putting a brake on the precipitous introduction of novel manufactured products into the market place. The manufacturing industry today is heavily constrained by environmental considerations, and all indications are that the manufacturing industry of the future will be even more constrained. A glimpse of future regulatory constraints can be seen in some of the regulatory actions just adopted by the European Union as well as some under consideration in the same body. With its recent enlargement to 25 countries, the European Union is now a substantial market of some 455 million people (1.6 times the U.S. population) and a GDP of €9.6 trillion (on par with that of the U.S. and about twice that of Japan. See Table 3.2.1). This represents considerable leverage over the manufacturing world, and globalization of manufacturers, suppliers, and distributors ensures that a decision taken by the European Union will have a wide-ranging effect across the entire manufacturing world. The following paragraphs describe the nature of the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and the Waste from Electrical and Electronic Equipment (WEEE) directives and use them as an example of the effect of ecological awareness measures on manufacturing.

### 3.2.1 RoHS and WEEE Directive

The RoHS/WEEE directive is intended to prevent the generation of electrical and electronic waste and to promote reuse, recycling and other forms of recovery in order to reduce the quantity of such waste to be eliminated, whilst also improving the

<table>
<thead>
<tr>
<th>POPULATION (million)</th>
<th>EU</th>
<th>U.S.</th>
<th>JAPAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP (trillions)</td>
<td>€9.6</td>
<td>$11.2</td>
<td>$4.5</td>
</tr>
</tbody>
</table>

*Table 3.2.1 – Comparison of EU, U.S. and Japanese Economies (Source: European Statistics for 2002 (€1=$1.1), European Union)*
environmental performance of economic operators involved in its treatment. The directive applies to a large segment of electrical and electronics equipment such as:
- Large and small appliances
- IT and telecommunications equipment
- Consumer equipment
- Lighting equipment
- Electrical and electronic tools
- Toys, leisure, and sports equipment
- Medical devices with some exceptions
- Monitoring and control equipment
- Automatic dispensers

and affects a wide range of environmental activities such as:
- Product design recommendations
- Treatment and regulatory techniques
- Recovery of WEEE (e.g., by 12/31/06, 80% rate of recovery by weight per appliance)
- Financing for collection, treatment, recovery, and disposal of WEEE (2004)
- Consumer information
- Reporting and penalties

The directive particularly targets the use of certain hazardous materials by mandating the replacement of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyl (PBBs), and polybrominated diphenyl ethers (PBDEs) in electrical and electronic equipment by other substances. This directive takes effect July 1, 2006, but exempts some products (military/aerospace, medical, server, and automotive applications) that may be covered by further legislation at a later date.

3.2.2 Impact on Brand Owners and Suppliers

The adoption of the RoHS/WEEE directive is having far-reaching effects on brand owners who are held directly responsible by the directive and the hundreds, maybe thousands, of suppliers (some of them small manufacturing enterprises) that supply them with components and subassemblies. The directive affects material and process selection and optimization aspects as well as capital expenditures for new process acquisition, R&D and support operations. An example of these effects is readily seen in the elimination of lead and flame retardant substances in the soldering and packaging of electronic components.

**Material Selection:** Elimination of the eutectic tin/lead (Sn/Pb) solder alloy has pushed manufacturers to scramble for a substitute. The main players seem to be settling on a tin/silver/copper (Sn/Ag/Cu) substitute with a higher melting point that may require a reflow temperature of up to 260°C (This is up to 50°C higher than what is needed for eutectic Sn/Pb alloy.). This higher temperature in turn leads to increased energy consumption, material redesign of some plastic encapsulated component families which
cannot tolerate this higher temperature, as well as the redesign, in some cases, of complete opto-electronic products.

- Tyco Electronics has started using higher temperature plastics for some parts.
- Agilent Technologies reports that the higher soldering temperature is believed to cause plastic lenses for Light Emitting Diodes (LEDs) to deform, lens coatings to show damage and light transmission properties and electrical parameters to change.
- Dell has already taken steps to eliminate the soon to be banned (July 1, 2006) PBBs and PBDEs flame retardants from its computer parts. [INFORM, 2003]

**Process parameters and equipment:** The adoption of a new soldering alloy based on the Sn/Ag/Cu system wipes out a large body of knowledge, experience and procedures accumulated over the years on the use and optimization of reflow/wave soldering conditions using the eutectic Sn/Pb alloy. New knowledge, experimentation and procedures must be developed for the substitute alloy. New equipment to handle the higher temperature and other process characteristics (say, soldering under a nitrogen atmosphere) of the new alloy may even be required.

- “The conversion is not likely to be smooth. It will add to our production cost.” STM Electronics (Spencer Chin, 2001).
- “If we can drive the temperature toward 230°C, there may be less of an impact on Original Equipment Manufacturers (OEMs). There is a lot of testing being done.” Intel’s McManus (Spencer Chin, 2001).
- “For Storage Technology Corp., a maker of large disk arrays and tape drives, lead-free assembly would necessitate major changes in its production set up.” (Spencer Chin, 2001).

Market leaders and most particularly large multinational companies are committing significant resources into research to meet the new RoHS/WEEE directive.

- Matsushita is reported [INFORM, 2003] to have expended $43 million for the conversion of its worldwide operations to handle lead free solder.
- Motorola is ahead of the game in phasing out lead-bearing solders because of its substantial business with Japan, where the Ministry of International Trade and Industry (MITI) has been phasing in programs to control and restrict lead-bearing products.
- Other large manufacturing firms are also eliminating lead-bearing solders for the worldwide distribution of their products. Hitachi by 2004, Mitsubishi by 2005 and Sony by 2006 [Vianco, 2003]

Small manufacturing enterprises (SMEs) with fewer resources for R&D, smaller market share or perhaps a less progressive approach are lagging behind. They will ultimately have to bear the cost of this conversion or risk the loss of market share and access to their big customers. They will feel the pressure of regulatory legislation over which they have no control but also experience new demands through the supply chain from their powerful customers. Sony for example is widely reported to have established the Global Green Partnership program which, for the first time, calls upon its suppliers to undertake
their own laboratory analysis of all materials supplied to Sony and then provide Sony with the results of the analysis.

The previous discussion provides but a small glimpse of the impact of ecological legislation adopted last year in the EU. All indicators point to the conclusion that the future will usher in more legislation, not less, and with wide ranging implications for the manufacture, distribution and after life disposal of consumer goods. Looming over the horizon is the EU Registration, Evaluation and Authorization of Chemicals (REACH) program. The program seeks to force industry to reevaluate some 30,000 chemical substances over a period of 11 years (2% of commercialized molecules). The REACH legislation is strongly opposed by industry, which will absorb the cost of this reevaluation and sees in such a program a recipe for added cost, deindustrialization of Europe and manufacturing job losses. Cost estimates of such a program vary widely: €30-50 billion according to industry, €4 billion according to Greenpeace and €11 billion according to the EU Commission studying the problem. While the heads of government of the three largest EU members (France, Germany and the U.K.) have managed to put a brake on the original proposal, a compromise proposal that would exempt synthetic polymers used in textiles, plastic adhesives and paints is emerging. Public opinion in Europe is reported to be heavily affected by the results of a stunning test conducted by the World Wildlife Fund (WWF) which strongly supports passage of the REACH legislation [Calinon, 2004]. The WWF collected blood samples from 47 volunteers from 17 European countries, including 39 members of the European Parliament. The samples were tested for the presence of 101 chemicals grouped into 5 chemical families: organic-chloride pesticides, polychlorobiphenyls, brominated flame retardants, phthalates and perfluorated compounds. Not less than 71 out of the 101 chemical substances were identified in the blood of the subjects. All samples were contaminated by at least one substance from each of the 5 families. On average, each individual had about 41 chemical substances (the high was 54) with levels of contamination sometimes 10 times higher than those found in workers directly exposed to those chemicals at the workplace. The final story of the REACH program remains to be told.

In addition to mandatory regulations, SMEs will also be affected by voluntary standards and policies emanating from international organizations, associations of large manufacturers, individual countries or states. An example of this is readily seen in the current ISO 14001 EMS (Environmental Management System) voluntary standard. This standard is perhaps the most recognized EMS in the world, but it is widely acknowledged as only a first step in the creation of a sustainable future. Large corporations such as GM are reported to be demanding that first tier suppliers demonstrate compliance with that voluntary standard. GM is not alone in demanding such compliance, as Ford and Toyota are also beginning to look at suppliers’ environmental performance. In a survey implemented by the International Network for Environmental Management [Environmental Mgmt., 1998], some of the internal obstacles to implementation cited by SMEs include cost, lack of commitment, dubious expected benefits, lack of knowledgeable personnel, and the voluntary nature of the standard. One of the most important factors that can encourage implementation, however, was supply chain pressure.
Ecological awareness, expressed through voluntary standards or mandatory legislation, will likely be an important driver of future manufacturing activities. SMEs will be most vulnerable because of limited resources and uncontrollable pressure through the supply chain. Their small size and lack of bureaucratic inertia may, however, give them the ability to respond with innovative solutions to future challenges. One of the most proactive responses to environmental challenges found in the literature was articulated by one of the world’s largest manufacturers of appliances. Electrolux actually lobbied for passage of the WEEE directive and viewed this as an opportunity that “creates a level playing field in which manufacturers will seek competitive advantages through design-for-recycling programs and investments in efficient handling systems for waste appliances.” (See Exhibit 3.2.1 for a complete Electrolux statement of its view.) At the other end of the spectrum are manufacturers that cling to the belief that lobbying for the reversal of legislation is the way out of the problem.

Exhibit 3.2.1 – The WEEE Directive: Electrolux’s Perspective

Electrolux was actively involved in the process that led to the adoption by the European Union of the Waste Electrical and Electronic Equipment (WEEE) Directive in late 2002.

The WEEE Directive establishes producer responsibility for financing of recycling and final disposal of many electrical goods, including almost all household products manufactured by Electrolux.

As the world’s largest manufacturer of powered appliances and an industry leader in environmental protection, Electrolux accepts its responsibility to ensure proper disposal of its products when they are no longer useful. We believe the WEEE Directive can create a level playing field in which manufacturers will seek competitive advantages through design-for-recycling programs and investments in efficient handling systems for waste appliances.

A central question in the four-year process that led to adoption of the WEEE Directive was individual versus collective producer responsibility. Under collective responsibility, manufacturers would all have paid the same amount for recycling and disposal, regardless of maker or whether one product was easier to recycle than another. Individual responsibility, on the other hand, specifies that each manufacturer must pay the costs associated with recycling its own products.

Electrolux joined with the World Wildlife Fund, the European Consumers Organization (BEUC) and other environmental organizations to argue that collective responsibility would not establish one of the main objectives of the WEEE Directive - encouraging investment in environmental improvements - since any cost savings gained through design and product development would be shared among all manufacturers.

By choosing individual producer responsibility, the EU made a wise decision that will harness the power of market forces to fuel the growth of an efficient recycling industry throughout Europe, and at the same time give manufacturers incentives to improve product design.

Source: Electrolux (www.electrolux.org/node494.asp)

3.3 DEMOGRAPHICS

U.S. Bureau of Labor statisticians, demographers and other research entities with an interest in the future state of manufacturing in this country foresee significant demographic changes in the labor work force over the coming decades. These changes, which include the size, composition and educational aptitude of the workforce, are of particular interest to the manufacturing industry. Unlike projections for Europe and
Japan, the size of the U.S. workforce is expected to continue to increase but at a slower rate. Figure 3.3.1 shows that the 2.6% labor work force growth rate of the 1970’s decreases to 1.1% in the 1990’s. This will be followed by projected stagnation at 1.1% during the 2000-10 decade and a significant projected decline to 0.4% from 2010-20.

![Figure 3.3.1 - % Growth Rate in U.S. Labor Workforce](Source: U.S. Census Bureau, [Fullerton et al., 2001])

The projected effect on manufacturing is that the future manufacturing firm will find it increasingly difficult to recruit the workforce it needs and most particularly during those periods of accelerated economic growth which require fast reaction time. The National Association of Manufacturers projects a shortage of 12 million workers by 2020. If accurate, this projected shortage will also affect the nature of the employee-employer relationship.

In addition to size, the composition of the future labor workforce is also expected to undergo a significant change. This expected change in age composition will be largely due to the “graying” of the so-called “baby boom” generation (see Census projections in Figure 3.3.2). On the other hand, racial and ethnic changes in labor workforce composition are expected to be affected largely by immigration patterns. Table 3.3.1 shows that Bureau of Labor Statistics projections expect the “over age 55” civilian labor workforce to jump from 12.9% of the total in 2000 to a projected percentage of 16.9% by 2010. This jump represents about 8.6 million people. On the other hand, the civilian non-institutional population 55 years and older will increase from 46 million in 1980 to 72 million by 2010. The impact of this graying of the population on manufacturing is expected to manifest itself in the nature and mix of goods and services. An aging population with significant purchasing power will evolve a different perception of manufactured products to satisfy its special needs for safety, comfort, assisted use of goods and increased services.
In addition, the mix of goods and services will also be affected by the demand for manufactured healthcare goods (e.g., implantable devices, monitoring devices etc.) and services which are expected to increase significantly. Bureau of Labor Statistics figures also show that civilian labor participation rate for people 55 years and older is expected to rise from 32.3% in 2000 to 37.1% in 2010. This increase in older population in the workforce, in conjunction with the decrease in overall growth rate will mean that tomorrow’s manufacturers will need to adapt their compensation, benefits and work schedules in order to retain an older workforce eligible for retirement.

The third demographic trend of interest is the persistence of a so-called skills gap. The NAM maintains that U.S. manufacturers face a persistent skills gap in the workforce today, despite the economic downturn and despite billions of dollars spent on education and training. In a survey of 119 manufacturers in the Mid-Atlantic region, the Federal Reserve Bank of Philadelphia reported that more than half of the 93 firms which hired people recently found it difficult to find people with the right skill set. Figure 3.3.3 shows the % of applicants lacking required skills for the job.

The increase in workers with post high school education from 1980 to 2000 is reported [Airing, 2002] to be at 19% whereas only a 4% increase is projected over the next 20 years. This is significant in light of the expectation that future growth in manufacturing is expected to be driven by high technology fields such as nanotechnology, biotechnology and information technology. In a report prepared for the National Science Foundation, the National Science Board (NSB, January 2004) observes that

In preparing Indicators 2004, we have observed a troubling decline in the number of U.S. citizens who are training to become scientists and engineers, whereas the number of jobs requiring science and engineering (S&E) training continues to grow….These trends threaten the economic welfare and security of our country…. If the trends identified in Indicators 2004 continue undeterred, three things will happen. The number of jobs in the U.S. economy that require science and engineering training will grow; The number of U.S. citizens prepared for those jobs will, at best, be level; and the availability of people from other countries who have science and engineering training will decline, either because of limits to entry imposed by U.S. national security restrictions or because of intense global competition for people with these skills.
Figure 3.3.2 – U.S. Population Projections
(Source: U.S. Census Bureau, International Data Base)
<table>
<thead>
<tr>
<th>Year</th>
<th>Civilian Labor Force 55 and older* (% of total)</th>
<th>Civilian non institutional population 55 and older* (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>15 (14.1%)</td>
<td>46 (27.3%)</td>
</tr>
<tr>
<td>1990</td>
<td>15 (11.9%)</td>
<td>50 (26.4%)</td>
</tr>
<tr>
<td>2000</td>
<td>18 (12.9%)</td>
<td>56 (26.9%)</td>
</tr>
<tr>
<td>2010</td>
<td>26.6 (16.9%)</td>
<td>72 (30.7%)</td>
</tr>
</tbody>
</table>

*Millions, Data extracted from Fullerton and Toosi [Fullerton et al., 2001]

**Table 3.3.1 – Civilian Labor Force Projections**

![Bar chart showing percent of applicants lacking required skills in specific areas](image)

*Figure 3.3.3 – Percent of Applicants Lacking Required Skills in Specific Areas (Source: Federal Reserve Bank of Philadelphia, April 2004)*

The perceived skills gap is expected to be compounded by the so-called “reverse brain drain.” This “reverse brain drain” refers to the proportion of foreign trained scientists, engineers and other graduates who elect, or are now actively enticed, to return home to fast growing economies such as India, China and South Korea. Olian [Olian, 2003] reports that now more than half of U.S. graduates with engineering doctorates return to their home countries once they complete their degrees. The proportion of foreign graduates with doctorate degrees in science and technology has grown considerably over the last several years (see Figure 3.3.4). A persistent skills gap will also be aggravated by
expected immigration patterns said to be dominated by immigrants with low technical skills and no tradition of post secondary education.

Figure 3.3.4 – Doctorates Earned in the U.S. (Source: NSF, 2004)

“It is always good to be in an industry with demographics on its side.”
GE’s J. Immelt commenting on his acquisition of Ammersham (maker of drugs to enhance imaging) to complement GE’s medical imaging hardware.
3.4 TECHNOLOGY

Technological innovations have had, throughout the last two centuries, a profound and disruptive effect on the manufacturing industries of this country and the rest of the world. The development of the railroad enabled manufacturers to reach bigger markets across great distances. The telephone led to a significant breakthrough in information technology and enabled large scale, centrally managed manufacturing firms to operate. The development of the internal combustion engine and its adaptation to transportation systems (cars and trucks) spawned one of the greatest, large scale manufacturing industries of the 20th century and fueled the manufacturing boom of the 1920’s. It also breathed life into a number of other manufacturing industries such as rubber, glass, petroleum, machinery, textiles and leather.

Radio, plastics, and the transistor also spawned manufacturing industries, which in some cases had no predecessors, and have since had a profound effect on manufacturing industries and everyday life. It is therefore not unreasonable to expect that the future will continue to spawn new technological developments that are not simple incremental upgrades but rather radical developments that will also have a significant impact on the future of the manufacturing industry.

Nor is it surprising that a number of studies that thought to peek into the future of manufacturing industries around the world placed a great deal of attention on science and technology developments as important drivers of future manufacturing activities. One of the most comprehensive and focused studies [Fraunhofer Institute, 2003a] encountered in the literature was sponsored by the European Union under The Future of Manufacturing in Europe 2015-2020: The Challenge of Sustainability. A major objective of this study was the identification, mostly by the way of Delphi surveys, of the dominant technological trends that will shape the future of the manufacturing industry. Table 3.4.1 shows, in the case of discrete parts and process manufacturing, a summary of the major technological trends that experts have identified as significant drivers of future manufacturing activities [Fraunhofer Institute, 2003b].

In this country, a similar effort was undertaken by the National Research Council Board on Manufacturing and Engineering Design under the heading of Visionary Manufacturing Challenges for 2020 [National Research Council, 2002]. Table 3.4.2 summarizes the emerging manufacturing foci identified by groups of experts again using Delphi surveys as the main investigative tool.

Accounting for the differences in the choice of words and descriptions used to convey these emerging manufacturing foci, one notices a large degree of agreement between the drivers identified by both studies. The future manufacturing foci that invariably stand out on the top of the list of these studies as well as on the lists of other studies and commentaries found in the open literature, the press and other media include the fields of nanotechnology and biotechnology. As a cross-cutting technology, nanotechnology is expected to facilitate technological change that refines and expands existing technologies.
Table 3.4.1 – Summary of the Major Technological Trends That Act as Significant Drivers of Future Manufacturing Activities (Source: Fraunhofer Institute for Innovation Research, 2003b)

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISCRETE PARTS AND PROCESS MANUFACTURING</td>
<td></td>
</tr>
<tr>
<td>NEW PROCESSING TECHNOLOGIES FOR NEW MATERIALS</td>
<td></td>
</tr>
<tr>
<td>MINIATURIZATION (MICROHANDLING, MICROMACHINING, METROLOGY)</td>
<td></td>
</tr>
<tr>
<td>NANOTECHNOLOGY IN MANUFACTURING</td>
<td></td>
</tr>
<tr>
<td>MECHATRONICS</td>
<td></td>
</tr>
<tr>
<td>MODELLING AND SIMULATION</td>
<td></td>
</tr>
<tr>
<td>PRODUCT LIFE CYCLE PLANNING</td>
<td></td>
</tr>
<tr>
<td>FLEXIBLE MANUFACTURING SYSTEMS</td>
<td></td>
</tr>
<tr>
<td>PROCESS INTEGRATION</td>
<td></td>
</tr>
<tr>
<td>PROCESS CONTROL AND SENSOR TECHNOLOGY</td>
<td></td>
</tr>
<tr>
<td>NEAR AND NET SHAPE PROCESSING</td>
<td></td>
</tr>
<tr>
<td>PROCESS IMPROVEMENT AND DEVELOPMENT</td>
<td></td>
</tr>
<tr>
<td>CATALYSIS</td>
<td></td>
</tr>
<tr>
<td>BIOTECHNOLOGY</td>
<td></td>
</tr>
<tr>
<td>MEMBRANE TECHNOLOGY</td>
<td></td>
</tr>
<tr>
<td>BIOFEEDSTOCK</td>
<td></td>
</tr>
<tr>
<td>NON-FOSSIL HYDROGEN</td>
<td></td>
</tr>
<tr>
<td>REPLACEMENT OF HAZARDOUS SUBSTANCES</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3.4.2 – The Emerging Manufacturing Foci Identified By Groups of Experts, (National Research Council Board on Manufacturing and Engineering Design, 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCURRENCE IN ALL OPERATIONS</td>
</tr>
<tr>
<td>System modeling capabilities</td>
</tr>
<tr>
<td>Modular and adaptable design methodologies</td>
</tr>
<tr>
<td>Adaptable process and equipment</td>
</tr>
<tr>
<td>INTEGRATION OF HUMAN AND TECHNICAL RESOURCES</td>
</tr>
<tr>
<td>Systems models of manufacturing operations</td>
</tr>
<tr>
<td>Unified methods and protocols for information exchange</td>
</tr>
<tr>
<td>Process for development, transfer and utilization of technology</td>
</tr>
<tr>
<td>New education methods and tools</td>
</tr>
<tr>
<td>Human machine interfaces</td>
</tr>
<tr>
<td>Reconfigurable processes and systems</td>
</tr>
<tr>
<td>ENVIRONMENTAL COMPATIBILITY</td>
</tr>
<tr>
<td>Modeling and risk assessment</td>
</tr>
<tr>
<td>Manufacturing processes with zero waste</td>
</tr>
<tr>
<td>Reduced energy consumption</td>
</tr>
<tr>
<td>RECONFIGURABLE ENTERPRISES</td>
</tr>
<tr>
<td>Enterprise reconfiguration</td>
</tr>
<tr>
<td>Organizational reconfiguration</td>
</tr>
<tr>
<td>Reconfiguration of manufacturing operations</td>
</tr>
<tr>
<td>INNOVATIVE PROCESSES</td>
</tr>
<tr>
<td>Nanotechnology</td>
</tr>
<tr>
<td>Biotechnology</td>
</tr>
</tbody>
</table>
as well as lead the way to more revolutionary applications. The National Nanotechnology Initiative defines “nanotechnology” as a field that includes the following technologies:

1. Research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range.
2. Creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size.
3. Ability to control or manipulate on the atomic scale.

M.C. Roco (2001) of the National Science Foundation observes that a worldwide effort is underway in this area with governments, research bodies and private entities spending an estimated $3 billion in 2003 on nanotechnology research. In the U.S., $800 million in funding was allocated in 2004 to the National Nanotechnology Initiative (NNI), with the U.S. House of Representatives making provisions to infuse some $2.36 billion into various nanotechnology programs over the next 3 years. A number of Federal departments and agencies are involved in this effort and their focus spans a number of scientific fields as shown in the Tables 3.4.3 and 3.4.4 below.

<table>
<thead>
<tr>
<th>Department/Agency</th>
<th>FY 2000 NNI Budget</th>
<th>FY 2001 Enacted</th>
<th>FY 2002 Request/Enacted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department of Defense</td>
<td>70</td>
<td>110</td>
<td>133 / 180.0</td>
</tr>
<tr>
<td>Department of Energy</td>
<td>58</td>
<td>93</td>
<td>97 / 91.1</td>
</tr>
<tr>
<td>Department of Justice</td>
<td>-</td>
<td>-</td>
<td>1.4 / 1.4</td>
</tr>
<tr>
<td>Department of Transportation (FAA)</td>
<td>-</td>
<td>-</td>
<td>- / 2</td>
</tr>
<tr>
<td>Environmental Protection Agency</td>
<td>-</td>
<td>-</td>
<td>5 / 5</td>
</tr>
<tr>
<td>National Aeronautics and Space Admin.</td>
<td>5</td>
<td>20</td>
<td>46 / 46</td>
</tr>
<tr>
<td>National Institutes of Health</td>
<td>32</td>
<td>39</td>
<td>45 / 40.8</td>
</tr>
<tr>
<td>National Institute of Standards and Tech.</td>
<td>8</td>
<td>10</td>
<td>17.5 / 37.6</td>
</tr>
<tr>
<td>National Science Foundation</td>
<td>97</td>
<td>150</td>
<td>174 / 199.0</td>
</tr>
<tr>
<td>U.S. Department of Agriculture</td>
<td>-</td>
<td>-</td>
<td>- / 1.5</td>
</tr>
<tr>
<td>Total**</td>
<td>270</td>
<td>422</td>
<td>518.9 / 604.4 (+43%)</td>
</tr>
</tbody>
</table>

(**) Figures are not available for five organizations that participate in the federal nanotechnology investment starting with January 2001: Department of Commerce (DOC), Department of State (DOS), Department of Treasury (DOTreas), NOAA, and Nuclear Regulatory Commission (NRC)

Table 3.4.3 – Summary of Federal Nanotechnology Investment in FY 2002 Budget Request (in million of dollars)(Roco, 2001)
<table>
<thead>
<tr>
<th>Agency</th>
<th>DOD</th>
<th>DOE</th>
<th>DOJ</th>
<th>EPA</th>
<th>NASA</th>
<th>NIH</th>
<th>NIST</th>
<th>NSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental research</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nanostructured materials</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Molecular electronics</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
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<tr>
<td>Spin electronics</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab-on-a-chip (nanocomponents)</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Biosensors, bioinformatics</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Bioengineering</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Quantum computing</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
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<tr>
<td>Measurements and standards for tools</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Nanoscale theory, modeling, simulation</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
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<tr>
<td>Environmental monitoring</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Nanorobotics</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
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<tr>
<td>Unmanned missions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>International collaboration</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
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<tr>
<td>Nanofabrication user facilities</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Table 3.4.4 – Examples of Proposed NNI Interagency Collaborative Activities (Roco, 2001)

Overseas, Japanese investment in this area was estimated at $750 million in 2002 while the EU is reported to have given nanotechnology a special place in its Sixth Framework Program (www.researchandmarkets.com). The scope and potential impact of the science and technology is wide. Roco identifies the following potential applications:

- **Manufacturing**: better, lighter and stronger materials that can combine desired properties and could not earlier be made by chemistry are now possible due to nanotechnology.
- **Electronics**: nanotechnology is expected to generate $300 billion worth of production to the semiconductor industry. Couple this to the other integrated circuits sales and the scope for further business is truly enticing.
- **Pharmaceuticals**: half of the current world production of pharmaceutical products is going to use nanotechnology in the near future. This could translate to roughly $180 billion in the next 10 years.
- **Chemical Plants**: nanostructured catalysts are used extensively in the petroleum and chemical processing industries and their use is poised to involve a value of $100 billion in the next 10 years.

Biotechnology on the other hand is expected to generate medical advances that will further extend life expectancy and improve the quality for life for those with chronic illness and disabilities. Likewise, biotechnologies to improve industrial production processes and advance the ability to understand and manipulate living materials promise to address many significant challenges facing society. A comprehensive survey carried
out by the U.S. Commerce Department’s Technology Administration provides a snapshot of the type of firms and activities ongoing in this field (Bureau of Industry and Security, October 2003). Some of the survey’s findings:

- Firms engaged in biotechnology activities vary greatly in size and scope. They range from small, dedicated biotechnology companies that are R&D-intensive and operate primarily on venture capital, grants, initial public offerings (IPOs) and collaborative agreements, to large, diversified companies that have greater in-house resources and well-established production and distribution systems.

- Larger firms account for the majority of net sales and operating income of businesses with biotech activities, although 90% (917 firms) of survey respondents had 500 or fewer employees. Only 19 firms (2%) reported more than 15,000 employees, while 600 (58%) had fewer than 50.

- Survey respondents that are engaged in biotechnology research, development, and applications reported that in 2001 they had more than 1.1 million employees, total annual net sales of about $567 billion, operating income of $100.5 billion, capital expenditures of $29.5 billion, and R&D expenditures of $41.6 billion.

- For 90% of firms, biotech-related business lines accounted for more than 75% of total net sales, employment, and operating income. These companies generally are smaller firms with fewer than 500 employees. For all respondents, biotechnology-related business lines accounted for almost 40% of total R&D expenditures.

- International markets accounted for at least 16% of firms’ biotechnology-related net sales or $8 billion in revenues in 2001. The leading foreign market for biotechnology exports is Europe (56% of export revenues), followed by the Asia/Pacific region (24%). Almost one-quarter of companies indicated that they plan to expand into a foreign market as part of their near-term competitive strategy.

- Patent data underscore the dynamic and rapidly evolving nature of biotechnology. In the last quarter of 2002, companies reported 33,131 pending applications for biotechnology products or processes, compared with 23,992 current portfolio patents.

Concrete manufacturing applications of these technologies in the near future, however, are hard to come by as it seems that a great deal is still in the research and experimental stages, mainly with instrumentation. For this reason, this section will focus on a set of emerging technological drivers which are more in line with our time horizon (2010-2015) and which are already emergent in some of today’s manufacturing activities. These drivers include hydrogen fuel cells and radio frequency identification (RFID) tags.

### 3.4.1. Hydrogen Fuel Cells

The first one of our technological drivers is associated with the transportation industry and its reliance on the internal combustion engine. Reliance on the internal combustion engine is increasingly in conflict with two national issues: the nation’s dependence on foreign oil and the effect of burning fossil fuel on the environment. President Bush articulated the issue this way:
It’s important for our country to understand that by being bold and innovative, we can change the way we do business here in America, we can change our dependence upon foreign sources of energy; we can help with the quality of the air; we can make a fundamental difference for the future of our children. (Bush, 2003)

The goal of the Bush administration as articulated by the U.S. Department of Energy is to achieve commercially viable fuel cell systems in the 2015 timeline. Historians of science and technology recall that within a decade of the introduction of the Model T in 1908, the horse drawn carriage industry virtually disappeared. Will the eventual successful development and commercialization of hydrogen fuel cells coupled to electric motors have as great an impact on the internal combustion engine and its myriad of associated manufacturing activities?

Several developments suggest that a serious effort is underway by both government and industry to explore the feasibility and commercial viability of this alternative power train technology. In this country, the following events stand out:

- In the 2003 State of the Union Address, the President announced a $1.2 billion initiative to reverse the country’s growing dependence on foreign oil by developing commercially viable Hydrogen Fuel Cells (HFC) to power cars, trucks, homes and businesses with no pollution or green house gas emissions [http://fossil.energy.gov/programs/fuels/]
- April 13, 2004, the Honda Motor Company announced the delivery of two Honda FCX hydrogen-powered fuel cell vehicles to the city of San Francisco. This brings to 12 the total number of Honda fuel cell cars in the U.S. and Japan. San Francisco runs a fleet of more than 700 alternative fuel and advanced technology vehicles and the city intends to create a hydrogen-refueling infrastructure to support regular daily operation of the vehicles. The Honda FCX car is a 4 passenger car with a maximum output of 60KW (80HP), 201 lb-ft of torque, maximum speed of 93 mph and vehicle range of 160 miles [Honda.com, 2004].
- April 27, 2004, Secretary of Energy Spencer Abraham announced about $350 million in hydrogen research projects or nearly one third of the President’s $1.2 billion commitment to bring hydrogen and fuel cell technology from the laboratory to the showroom. Funded projects involve some 30 lead organizations and include over 100 partners. [http://www.eere.energy.gov/hydrogenandfuelcells/recent_awards.html]
- G. Richard Waggoner Jr., the chairman and CEO of General Motors, has set the following hydrogen fuel cell technology goals for his company: $50/KW tank-to-wheel cost, commercial viability by 2010, and GM as the first company to build and sell one million such cars profitably (the time for this latter goal has not been set) [Vasilash, 2004].

The next paragraphs provide an overview of hydrogen fuel cell technology, some of the roadblocks which need to be overcome and speculation on the impact of such technology on future manufacturing activities.
Hydrogen Fuel Cell Technology
A fuel cell is an electrochemical device with no moving parts, which creates electricity by an electrochemical process using hydrogen and oxygen without combustion. It operates in a manner similar to that of a battery that can be recharged while power is being drawn from it. Instead of recharging using electricity, a fuel cell uses hydrogen and oxygen. The byproducts of this process are heat and water, with no emission of harmful gases. Most fuel cell systems consist of two basic components:

**Fuel Processor**: This first component of a fuel system is required for the use of hydrogen rich fuels like methanol (hydrocarbons), and not for pure hydrogen. This processor separates the hydrocarbons into hydrogen and carbon compounds—reformate. This reformate is then purified to prevent impurities (carbon) from entering the fuel cell system.

**Fuel Cell Stack**: A fuel cell consists of two thin electrodes – a porous anode and a cathode, which sandwich an electrolyte membrane. The anode is porous so that hydrogen can pass through it, and the cathode is porous so that oxygen can pass through it.

Most fuel cells are of the Polymer Electrolyte Membrane/Proton Exchange membrane (PEM) type and these are the ones under consideration for the automobile industry. The PEM is a thin, solid organic compound with the thickness of 2-7 sheets of paper. This electrolyte conducts protons (the positively charged ion) but not the electrons (the negatively charged ion). Moisture aids in the easy conduction of ions through it. Flow plates surround the electrodes-electrolyte sandwich in order to:
- Channel the hydrogen and oxygen to the electrodes
- Channel water and heat away from the fuel cell
- Conduct electrons from anode to the electrical circuit and from the circuit to cathode.

A fuel cell works in a manner similar to reverse electrolysis. During electrolysis, current running through water produces hydrogen and oxygen, the components of water. In 1839, Dr. William R. Grove showed that combining hydrogen and oxygen would produce water and an electric current. For the above reason, hydrogen is often referred to as a secondary energy carrier. A schematic in shown in Figure 3.4.1 with the principles of operation shown in Figure 3.4.2.

A single fuel cell is insufficient to run any major conventional application. To produce power in large amounts, many such single fuel cells are combined to form a stack. A typical fuel cell stack may consist of hundreds of fuel cells. Figure 3.4.3 shows the fuel cell stack used by the Honda FCX automobile.
Figure 3.4.1 – Basic Concepts of Hydrogen Fuel Cells  
(http://www.fuelcells.org/basics/how.html)

Step 1:
Hydrogen from the storage tank is channeled to the anode through the flow plates. The negatively charged anode catalyst splits the hydrogen atom ($\text{H}_2$) into a positively charged proton and a negatively charged electron. The electrolyte membrane permits the passage of protons ($\text{H}^+$) through it but blocks the flow of electrons ($\text{e}^-$).

Step 2:
The positively charged $\text{H}^+$ ions move through the PEM towards the cathode. Meanwhile the electrons, which are unable to pass through the membrane, increase in number. This builds up an electrical charge. When a circuit is created between the two sides of the membrane, the electrons are able to flow through the circuit. This flow of electrons forms an electric current, in the form of direct current. Oxygen is also fed into the cell through the flow plates into the cathode catalyst.
Step 3:
At the cathode, the protons H\(^+\), electrons e\(^-\) and oxygen combine to form water and heat. This water is discharged as vapor through the flow plates for usage.

*Figure 3.4.2 – Theory of Operation of Hydrogen Fuel Cell*
(Source: Schatz Energy Research Center, Humboldt University)

*Figure 3.4.3 – Fuel Cell Stack of Honda (world.honda.com/factbook/auto/)*

In theory fuel cells could power anything that could work on electricity. Contemplated applications include:

**Transportation:** Fuel cells could be used to generate electricity as a substitute to batteries in electricity operated vehicles. Moreover, recharging of batteries is more time consuming than refueling the hydrogen tank. Fuel cell drive prototypes are now being developed and tested. They could be used to drive light automobiles and also trams. Global auto companies like Honda, Chrysler etc. have already built prototypes of fuel cell vehicles (FCV). They have also been used to provide auxiliary power in aerospace applications.

**Stationary Power:** Fuel cells could also be used for backup power, power for remote locations, etc. Phosphoric acid fuel cells have been used in most of the applications of this kind. They have not been used yet in the residential market.

**Portable Power:** Fuel cells can also be used to power portable devices like handheld electronics, laptop computers, cameras and also larger equipment like portable generators. PEM and Direct Methanol fuel cells are the two most widely used types for these kinds of applications.
Roadblocks to Deployment

There are a number of significant barriers to the successful implementation of fuel cell technology. These barriers include:

**Cost:** This is currently the greatest challenge facing the technology. This technology requires highly expensive metals and catalysts which are able to withstand very high temperatures.

**Durability:** The metals and the catalysts are subjected to extremely high temperatures and chemical reactions, which decreases the efficiency and performance.

**Production:** Even though hydrogen is widely available in air, producing hydrogen for the cell is more expensive than conventional fuels. The process consumes a lot of energy.

**Storage/Safety:** Being a low density fuel, hydrogen requires a large amount of storage space, posing challenges for fuel cell vehicles. The drive range of a cell stack is less than that achieved by an IC engine. Concerns exist about the safety issues in the storage space.

**Ozone Depletion:** Research studies have indicated that large amounts of hydrogen could lead to depletion of the ozone layer that shields the earth from the harmful ultraviolet (UV) rays from the sun.

Potential Impact on Future Manufacturing Applications

As mentioned in the Futman report on the automotive industry [Fraunhofer Institute, 2003c], the transition from internal combustion engine to the hydrogen fuel cell will have significant impacts on the production methods, machine tools and other processes associated with the production of the internal combustion engine. Some of the potential impacts:

**Manufacturability:** According to GM’s L.D. Burks, V.P. of Research & Development [Vasilash, 2004], the transition from IC engine to HFC will result in a significant gain in manufacturability, since from a mechanical perspective, the HFC is a much simpler geometric design than the complex geometry and number of parts required in an ICE. This simpler design will also have about one tenth as many moving parts as an ICE and this implies considerable reduction in accuracy, precision, wear and lubrication requirements (see Figure 3.4.4).

**Process Machinery:** A typical ICE requires parts made by a significant number of traditional manufacturing processes including casting, forging, machining, powder metallurgy, surface treatment, drawing, extrusion and sheet metal work. The machine tool industry has historically worked hand in hand with the automotive industry and significant progress and developments in the machine tool industry were due in large part to the partnership between machine tool manufacturers and automotive builders. This special symbiotic relationship will be lost. HFC building processes will mostly involve sheet metal working, chemical and catalytic printing, adhesion, soldering and joining processes. These processes are likely to get increased interest and stimulus for development.

**Material Production:** A typical ICE requires an array of conventional ferrous and non-ferrous materials such as cast iron, steel, aluminum alloys. The HFC is an
assembly of specialty materials such as polymers for the proton exchange membrane and precious metals (platinum) for the electrodes. The transition from ICE to HFC will alter the equation for material processing and production. **Fuel Production:** The ICE supports a large part of the fossil fuel processing and gas production. DOE transition plans call for the production of hydrogen from natural gas and coal until better non-fossil fuel technology can be developed. **Assembly Lines:** ICE production typically requires separate plants for 4, 6, and 8-cylinder gas or diesel engines. The production of HFC involves stacking processes which should be invariant to the size of the stack.

![Image: Transformation from ICE to HFC](image)

**Figure 3.4.4 – Transformation from ICE to HFC**

### 3.4.2 Radio Frequency Identification (RFID) Tags

“The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.” Such is the characterization R. Want [Want, 2004] attached to RFID tags, the second technological trend selected for this report. These electronic devices, the size of a grain of rice, carry information and can be interrogated by a non-contact reader. They can be embedded in a wide variety of products, livestock and even under the skin of humans. The potential applications in the manufacturing and service industries as well as in the everyday life of the public are boundless. Some examples include:

**Supply Chain Management:** RFID is gaining popularity as a facilitator for overall supply chain efficiency and more and more companies are adopting it to remain competitive. Overall availability of information and real time tracking of items are some of the advantages that supply chains can use. Inventory management is yet another area that can use RFID to bring efficiency. Since a line of sight is not required, tagging gives total asset visibility and allows better management of the asset. Read/Write functionality can also offer considerable advantages. Major ERP
solutions providers (Oracle, SAP, and PeopleSoft) are also releasing versions and middleware that integrate/comply with RFID technology and standards. The U.S. military is also actively adopting the RFID technology for high value defense logistics.

**Retail and Distribution:** Wal-Mart, the world’s largest retailer, surprised its suppliers during the summer of 2003 when it announced an aggressive timetable for them to incorporate RFID tags on their shipments. Unlike barcodes, the digital tags can have processing and memory storage and thus carry significantly more information about a product. This ability will have a significant impact on the efficiency and management of the supply chain. Integrated with sensors, these tags can be imbedded into products and machines and interrogated to report an internal product or process condition.

**Sensors:** Tags that assess the pressure and temperature while a vehicle is in motion have been reported to be already in use (www.sciam.com) and major companies such as Michelin, Philips Semiconductors and BMW are also reported to be developing prototypes for the mass market (www.sciam.com).

**Aerospace and Transportation Industry:** Boeing and Airbus are working to promote RFID tags for major airplane parts. The project promotes RFID tags for particular jets and eventually all jets. Tagging large parts will provide increased visibility, greater inventory control and improve management of work in progress. Another area of impact would be in minimizing counterfeit parts, and tracking maintenance history.

The U.S. Transportation Security Administration estimates that the airline industry in the United States will have to spend about $5 billion over the next five to ten years to upgrade baggage screening systems to comply with laws passed after the Sept. 11, 2001 terrorist attacks. Airlines see RFID as one technology that can help them comply with the new regulations (See Figure 3.4.5 for an example of an RFID tag for airlines). Bags on a conveyor can be in any orientation, and currently readers are able to scan bar codes on baggage tags only 30 percent of the time, according to the FAA. RFID doesn't require line of sight, so it has the potential to dramatically improve the read rates. If successful, the new system would not only improve safety by ensuring that high-risk bags are screened, it would also reduce labor costs by eliminating the need to have security staff hand-search bags in the terminal.

![Figure 3.4.5 – A Matrics Bag Tag](Source: RFID Journal)

Beyond the security concerns, airlines are looking at RFID's ability to improve baggage sorting and tracking and to streamline check-in systems. RFID tags could
also be used in cargo and mail tracking, as well as to identify passengers enrolled in frequent-flier programs. Some airports are already deploying RFID technology to track bags. Instead of putting a disposable tag on each bag, they are tagging reusable plastic totes used to move bags around inside the airport. Brussels' Zaventem Airport and Stockholm's Arlanda Airport are set to go live with such systems this fall.

**Automobile Industry:** DaimlerChrysler is reported to be using them on vehicle manufacturing lines to transmit the color needed in the paint process. It is not too difficult to imagine that, when some of the roadblocks to this technology are overcome, and when price, processing power, and memory are right, the DaimlerChrysler experiment could then be expanded to all if not most manufacturing steps in a “lights out factory.” A printed circuit board could be launched as appropriate under information programmed into the RFID tag which would then help it navigate its way through a “lights out factory”, interact with required assembly processes and record process conditions for quality control and traceability. The impact on automation and mass customization of appropriate “products” would be tremendous.

To time and score the Indianapolis 500 event in May 2004, the event’s sanctioning body used an RFID-based system called TranX Pro. Made by AMB i.t. of Heemstede, Netherlands, the transponder-based, automatic identification and timing system is used by professional sports organizations worldwide to time and score everything from IndyCar racers to the Olympic Games. The combination of transponders affixed to the cars and antennas embedded in the asphalt help turn the 2.5-mile racetrack into a stopwatch, accurate and reliable enough to differentiate and verify the times of two or more cars passing the same point within 10,000ths of a second of each other. Each of the 33 cars starting the Indianapolis 500 carries a battery-powered transponder (see Figure 3.4.6) that constantly emits a seven-digit identification code on a low-frequency signal. As each car completes a lap, it passes over the detection loop at the start/finish line, which picks up the transponder’s unique ID code. Kevin Oonk, president of AMB i.t. U.S., which is based in Smyrna, Ga., says the AMB TranX Pro system’s read range between transponder and loop is about 2 feet. He says the loop can detect up to eight transponder signals at exactly the same time, so the system can read up to eight vehicles passing at exactly the same time.

![Figure 3.4.6 – TranX Pro RFID Tag](Source: RFID Journal)
**Other Applications:** Some of the other applications for RFID include:

- Automobile disable feature on keys.
- 'Speedpass' type payment system at gas pumps, restaurants, supermarkets,
- Automated toll collection systems on toll roads.
- Access control systems - parking lots, buildings, etc.
- Animal tracking - feeding systems, etc.
- Library checkouts.
- Embedded tags in currency.

The next paragraphs provide a very brief overview of this technology, some of the roadblocks that need to be overcome in the future, and a discussion of potential applications.

**RFID Technology**

RFID stands for Radio Frequency Identification, a form of identification that does not require line-of-sight for communication (unlike infrared or portable data terminals). It can also be termed as dedicated short-range communication (DSRC). There are usually three components in an RFID environment, namely a transceiver with decoder (interrogator), an antenna (coil), and a transponder (tag), as shown in Figure 3.4.7. In operation, the

![Figure 3.4.7 – RFID Environment (Source: RFID Journal)](image)
antenna sends out a radio signal that initiates the communication process with the transponder. The antenna acts as a link between the transponder and the transceiver. The communication process can be a simple read only process or it can be of a read/write nature. When a tag comes within range of a signal from the receiver, the tag is sensed and information from the transponder is sent to the receiver. In reverse, the transponder can also accept information. Once the communication link is established, information or data can be ported through standard interfaces to a host computer, printer, or programmable logic controller (PLC) for storage or action. Tags can be close proximity (inductive) systems to systems having range of tens of meters (radiating systems), without the need for line-of-sight, depending upon type of transponders and interrogation hardware.

**Types of RFID Tags (Active and Passive)**

RFID tags are categorized as either active or passive. Active RFID tags are powered by an internal power source and typically fall in the read/write category, i.e., tags that can be rewritten or modified. Active RFID tags are usually more expensive when compared to passive tags. The data capacity of an active tag usually depends on the nature of the requirement and can at times reach capacities in the order of megabytes. The internal power source of an active tag gives it a longer communication range. The tradeoff when it comes to active tags is greater size, greater cost and limited operational life (depending on the operating environment and battery type). Active tags are usually capable of operating over a temperature range of -50°C to +70°C.

Passive RFID tags don’t have an internal power source and they use the reader’s power to complete the information exchange process. Passive tags therefore are much smaller, lighter, and offer a virtually limitless operational life. Passive tags can also be of the read/write nature. The tradeoff in this case is shorter range and higher reader power requirements. The data capacity is also smaller compared to active tags. Read only tags are usually passive and are programmed with a unique data set (usually 32 to 128 bytes) that cannot be modified.

**Key Attributes of RFID**

Quite like bar codes, RFID acts as a facilitator or a support tool targeted towards process automation and operations management. It reduces labor, enables efficient use of data, improves productivity, and has the ability to improve customer support levels. However, unlike bar codes, RFID tags can bring in various other levels of efficiency:

- RFID does not require line of sight for exchange of data/information.
- They can be read through wood, plastic, cardboard, paint, snow, dirt, any material except metal. (Technologies are emerging that make use of RFIDs on metal surfaces possible. For example, Trolley Scan, South Africa, has developed a passive RFID transponder system that can be read at a distance of 11 meters, even when attached to metal (http://trolleyscan.com).
- Data/information exchange can be accomplished on the move and over a greater range.
- Speeds up to several megabits per second can be achieved.
- Tags can be reprogrammed on the fly (read/write tags).
- Tags can be used in harsh environments.
- Tags come in a variety of sizes, shapes, and forms.
- Multiple tags can be read in the same field dimension.
- Anti-collision technologies are making simultaneous use of multiple interrogators possible, thus bringing in more efficiency.
- Tags can contain much more information compared to bar codes (data capacity).
- Long life. Passive tags can have virtually limitless life since they have no moving parts or power source.
- Tags can be reused multiple times.
- No established health risks associated.

**Standards in RFID Communication**

The frequency ranges are generally distinguished for RFID systems as low or high. Figure 3.4.8 summarizes the concepts behind each of the two types. There are three regulatory areas, Europe and Africa (Region 1), North and South America (Region 2) and Far East and Australia (Region 3). Uniformity is being sought for carrier frequency usage, since each country manages its own frequency allocation within the guidelines set out by the three regions and respective governments. This non-uniformity is set to change with regions and organizations coming together to achieve some uniformity by the year 2010. Since UHF (Ultra High Frequency) can cover portals up to 9 feet wide, it is gaining industry support as the choice bandwidth for inventory tracking applications including pallets and cases. Three frequencies that are gaining attention as standards of the low, medium, and high ranges are 125 KHz, 13.56 MHz and 2.45 GHz. In the U.S. the UHF frequency standard is 915MHz while in Europe the UHF standard is 869 MHz. There are eight frequency bands being used across the globe for RFID applications.

**Industry Initiatives**

RFID has been praised by manufacturers and retailers for its ability to improve visibility about inventory and other data across the supply chain, which can increase product availability and help businesses reduce costs by trimming inventory levels. These companies along with government organizations are coming together to drive the RFID initiative, which is helping the proliferation and standardization of the technology. The key standardization bodies that are working on these issues include the American National Standards Institute, the International Organization for Standardization, Association for Automotive Identification and Mobility, and EPCglobal.

EPCglobal is a joint venture between EAN International and the Uniform Code Council (UCC). It is a not-for-profit organization entrusted by industry to establish and support the Electronic Product Code (EPC) Network as the global standard for immediate, automatic, and accurate identification of any item in the supply chain of any company, in any industry, anywhere in the world. The major objective of EPCglobal is to drive global adoption of the EPCglobal Network. The EPCglobal Network was developed by the Auto-ID Center, an academic research project headquartered at the Massachusetts Institute of Technology (M.I.T.) with labs at five leading research universities around the
An integrated circuit sends a signal to an oscillator that creates an alternating current in the reader's coil. This current generates an alternating magnetic field, serving as a power source for the tag. The field interacts with the coil in the tag, inducing a current that causes charge to flow into a capacitor where it is trapped by the diode. As charge accumulates in the capacitor, the voltage across it increases and activates the tag’s integrated circuit, which then transmits its identifier code.

The variations in current flow in the reader coil are sensed by a device that converts this pattern to a digital signal. The reader’s integrated circuit then discerns the tag’s identifier code.

Figure 3.4.8 – RFID Technology (a) Low Frequency System
(Source: Want, 2004)
1 An integrated circuit sends a digital signal to a transceiver, which generates a radio-frequency signal that is transmitted by a dipole antenna.

2 The electric field of the propagating signal gives rise to a potential difference across the tag's dipole antenna, which causes current to flow into the capacitor; the resulting charge is trapped there by the diode.

3 The voltage across the capacitor turns on the tag's integrated circuit, which sends out its unique identifier code as a series of digital high and low voltage levels, corresponding to ones and zeros. The signal moves to the transistor.

4 The transistor gets turned on or off by the highs and lows of the digital signal, alternately causing the antenna to reflect back or absorb some of the incident radio-frequency energy from the reader.

5 The variations in the amplitude of the reflected signal, in what is called backscatter modulation, correspond to the pattern of the transistor turning on and off.

6 The reader's transceiver detects the reflected signals and converts them to a digital signal that is regulated to the integrated circuit, where the tag's unique identifier is determined.

Figure 3.4.8 – RFID Technology (b) High Frequency System  
(Source: Want, 2004)
globe. The EPCglobal network uses radio frequency identification (RFID) technology to enable true visibility of information about items in the supply chain. The network is comprised of five fundamental elements:

- Electronic Product Code (EPC)
- ID System (EPC Tags and Readers)
- Object Name Service (ONS)
- Physical Markup Language (PML)
- Savant (software component).

EPCglobal recently released version 1.1 of the EPC Network that offers the complete set of technical specifications for every element in the EPC Network. EPC utilizes the basic structure of the Global Trade Item Number (GTIN). There are also other associated emerging standards like the ISO 18000 that allows any ISO 18000 chip to talk to any ISO 18000 reader at a given frequency. Some of the ISO 18000 standards:

- ISO 18000-1: Generic Parameters for Air Interface for Global Interface
- ISO 18000-2: Parameters for Air Interface <135 kHz
- ISO 18000-3: Parameters for Air Interface at 13.56 MHz
- ISO 18000-4: Parameters for Air Interface at 2.45 GHz
- ISO 18000-5: Parameters for Air Interface at 5.8 GHz
- ISO 18000-6: Parameters for Air Interface at 860-930MHz (proposed name change – UHF)
- ISO 18000-7: Parameters for Air Interface at 433.92MHz (proposed work item)

The U.S. Department of Defense is playing a big role in the standardization of various RFID technologies. The U.S. Food and Drug Administration is urging pharmaceutical companies to adopt radio frequency identification technology as a means to combat drug counterfeiting. Apart from independent and government organizations, major players in various industries having considerable clout in the industry are also adopting the technology. Some of the major players are Proctor & Gamble, Gillette, GE, Philips, Morris, Wal-Mart, Sun Microsystems, Microsoft, SAP, PeopleSoft, Oracle, DaimlerChrysler, Ford, GM, Dell, Harley Davidson, Michelin, Marks & Spencer, McDonald's, Metro Group (Germany), Benetton, Tesco, Exxon Mobil, BMW and Nokia to name a few. Philips and IBM have already inked a deal to work on the RFID technology together.

An example of a big player’s influence on market growth can be seen in Table 3.4.5 (data provided by Venture Development Corporation). Figure 3.4.9 shows growth in various global RFID markets.
Global Shipments of RFID Systems Segmented by Product Category

(Millions of Dollars)

<table>
<thead>
<tr>
<th></th>
<th>Base Year</th>
<th>Original Forecast</th>
<th>Adjusted Forecast</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>2003</td>
<td>2005</td>
<td>CAGR</td>
</tr>
<tr>
<td>Transponders</td>
<td>554</td>
<td>848</td>
<td>24%</td>
</tr>
<tr>
<td>Readers</td>
<td>272</td>
<td>371</td>
<td>17%</td>
</tr>
<tr>
<td>Software/Service</td>
<td>301</td>
<td>431</td>
<td>20%</td>
</tr>
<tr>
<td>Total</td>
<td>1128</td>
<td>1651</td>
<td>21%</td>
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</table>

Originally estimated to rise by 21% between the years 2003 and 2005, the near-term compound annual growth rate (CAGR) for RFID software and systems is now expected to surpass 37%. This is mostly due to RFID implementation by big players like Wal-Mart, Metro AG, Tesco, the U.S. Department of Defense and, most recently, Target.

Table 3.4.5 – Global Shipments of RFID Systems Segmented by Product Category
(Source: Venture Development Corporation)

Figure 3.4.9 – RFID Markets
(Source: TagSys.net, VDC)
Industry leaders like IBM, Intel, and Microsoft are already backing the RFID revolution and have announced technologies that use/facilitate RFID. Major players in the RFID market such as TagSys, Texas Instruments, Phillips, Motorola, Hitachi, and Intermec are investing in R&D and pilots in specific industries to understand growth opportunities for the RFID technology. Hitachi recently introduced world’s smallest RFID chip at a size of 0.3 millimeters square.

Apart from the industry leaders, other players in the market are also coming out with solutions that use RFID technology to drive efficiency. Another aspect to consider is the ongoing consolidation happening with the industry that will act as a catalyst to technology standardization. RFID technology is evolving rapidly, and with more standards emerging, adoption of RFID in the future as a global standard is inevitable. An extensive list of major RFID vendors can be found in Table 3.4.6.

Table 3.4.6 – Current RFID Vendors (Source: Integrated Solutions)

<table>
<thead>
<tr>
<th>Semiconductors Manufacturers</th>
<th>RFID, Inc. - Aurora, CO</th>
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<tbody>
<tr>
<td>Infineon Technologies - San Jose, CA</td>
<td>SAMSys Technologies - Ontario</td>
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<td>Philips Semiconductors</td>
<td>Savii Technology - Sunnyvale, CA</td>
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<td>Symbol Technologies - Holtsville, NY</td>
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<tr>
<td>TAGSYS - Doylestown, PA</td>
<td>TAGSYS - Doylestown, PA</td>
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<td>Texas Instruments - Plano, TX</td>
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<table>
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<tr>
<th>RFID Tags</th>
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<td>Alien Technology - Morgan Hill, CA</td>
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<td>AXCESS Inc. - Carrollton, TX</td>
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<tr>
<td>Brady Corp. - Milwaukee, WI</td>
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<tr>
<td>Checkpoint Systems - Thorofare, NJ</td>
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<tr>
<td>Datalogic - Hebron, KY</td>
</tr>
<tr>
<td>HID - Irvine, CA</td>
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<tr>
<td>ID Systems - Hackensack, NJ</td>
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<td>Indentec Solutions - British Columbia</td>
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<td>Intermec Technologies - Everett, WA</td>
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<td>Matrics - Columbia, MD</td>
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<td>Omron - Schaumburg, IL</td>
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<td>Parlex - Methuen, MA</td>
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<td>Quelis ID Systems - Quebec</td>
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<th>RFID Readers/Interrogators</th>
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Challenges

Like hydrogen fuel cells, RFID technology faces a number of issues that must be resolved prior to successful implementation. A number of these challenges are discussed below.

Privacy and Security
Privacy is a major concern hampering the adoption of RFID technology. Concerns over tracking by the retailer and government through products, clothes, and other personal items (currency, etc.) have already made the American Civil Liberties Union, the Electronic Frontier Foundation, the World Privacy Forum and a dozen other organizations ask for a voluntary moratorium on RFID technology in consumer goods. The fear of letting out purchasing habits and patterns to retailers and manufacturers is yet again fueling the concerns. That is also the case with the idea of giving the government the power to potentially track people using embedded RFID tags. Companies are also slow in adopting because of the fear of giving out company secrets and proprietary technology to competitors. In January EPCglobal selected VeriSign to operate RFID product code category. VeriSign is the world's leading provider of critical infrastructure and security services for Internet and telecommunications networks.

Lack of Global Standards
Since there are considerable initial investments and organizational changes for any manufacturer or supplier to consider before adopting RFID, the lack of a single standard across the market is slowing down the acceptance rate of the technology. Surveys have shown that a majority of suppliers are holding back on the technology because of lack of standards. Wal-Mart even with its considerable market clout is finding it difficult to make its top 100 suppliers meet the 2005 RFID compliance deadline. Currently, only 25% of Wal-Mart’s top 100 suppliers are in a position to meet the deadline. Standardization would be a critical issue especially when global value chains using RFID technology are concerned. Another issue is the presence of many proprietary protocols existing in the market today. Some of these protocols are owned by industry leaders and they see standardization as a threat to technology control and ownership. Organizations like EPCglobal are working towards bringing in a global standard; however, until such a standard is established, industry players would still be cautious about adopting RFID technology.

Data Volumes
With in-store deployment, it is predicted that Wal-Mart will generate over seven terabytes of operational RFID data everyday. Technology architectures currently in use are not prepared to handle this volume. Similar would be the case with data volumes associated with other supply chain implementations. Organizations will have to upgrade their IT/database infrastructure to efficiently keep pace with the amount of operational data generated to derive the full benefits of RFID adoption and implementation.
**Associated Infrastructure Cost**

This is another issue that is deeply related with the lack of a global industry standard for the RFID technology. Many first-tier suppliers don’t want to invest in a technology that is not yet standardized. Fear of obsolescence and/or emerging new standards is what is making the suppliers wait before committing to the technology. RFID tag costs vary a lot and can vary from less than $1 to $190 or more each. Interrogators can cost anywhere from $1,000 to $12,000 each depending on complexity of requirements. More than the cost, it is the magnitude of operational and cultural change that is deterring the suppliers. Also, a new technology can potentially create incompatibilities and issues with legacy systems and existing IT backbone within a company. AMR Research Inc. (Boston) estimates that suppliers will spend $10 million to $20 million each to meet Wal-Mart’s RFID compliance standards including hardware and integration with existing systems. At an average cost of $0.50 per tag, the industry is finding it difficult to justify the cost to put RFID tags into individual units. However, with advancements in technology, tags under $0.10 are becoming a reality. Cost reductions combined with emerging standards will eventually make the ROI figure attractive enough for suppliers to make the commitment. Compliance requirements from big players like Wal-Mart will also help the adoption process along. Diffusion of complementary technologies like GPS will also help RFID see global acceptance.

4. STRATEGIC RESPONSES

Following the identification and evaluation of global environment drivers, our focus shifted to the prospective identification and evaluation of strategic responses currently under implementation or likely to emerge as a response to the effects of global environment drivers. These strategic responses include the shedding of physical assets, the bundling of goods and services, flexibility and mass customization, e-collaboration and ecologically tolerant product design. Innovation, a key strategic competitive response in today’s environment was left out since it is the subject of a separate report for NIST [Warren, Wilson, and Susman, 2004].

4.1 SHEDDING OF PHYSICAL ASSETS

Traditional product manufacturers serving industrial markets with mature manufacturing technologies subject to increased global competition, over-capacity, price pressure, evolving customer preferences, and other market changes will look to shed physical manufacturing assets (or outsource) and exit asset-intensive, low margin activities. This scenario will seek to replace company-owned manufacturing with outside supply chain management while investing in intangible assets such as knowledge and brands. The trend is clearly manifest in the intentions of major U.S. manufacturers spanning aerospace, automobile, and semiconductor industries.
Aerospace: The future Boeing 7E7 – Under intense competition from Airbus for the civilian aerospace market, Boeing is taking a page out of its competitor’s playbook and turning to contractors in several countries to supply most of its future jetliner model. Japanese suppliers are making a strong bid to manufacture the wings [Acohido, 2003] (never before outsourced by Boeing) and are slated to build and supply about 35% of the airplane. Boeing is to build another 35% of the plane, while the rest is to be built and supplied by Alenia Aeronautica (Italy)/Vought Industries (Dallas) (26%) and a few others (4%). While outsourcing is not new to Boeing operations, outsourcing on this scale for a future airliner is a radical departure designed to move as much risk and cost off the books and shift the burden of hiring (during good times) and firing (during bad times) to major partners. As Mike Blair, Senior Vice President of the 7E7 Program, put it [Acohido, 2003], “Figuring out what the wings look like, figuring out how to put them on the airplane, understanding whether that is something our customers will buy, understanding how to integrate that stuff, that is the magic Boeing brings to this process.” While Boeing is clearly satisfied with this new emphasis on airplane knowledge assets, rather than the extent of manufacturing assets, the implications of this new business model for the thousands of suppliers who have traditionally dealt with Boeing are not trivial. These suppliers, many of whom are SMEs, clearly need to change their way of doing business and will have to figure out how to market, sell, and deliver their goods to new prime partners not under the same roof and scattered over several continents.

Automotive Industry: A similar trend is at work in some of the next-generation automobile assembly plants. Ford’s newly inaugurated 155-acre “Supplier Manufacturing Campus” [Weber, 2003] is an experiment aimed at bringing nine suppliers of major components and sub-assemblies such as stamping, door components, plastic components, suspension units, fuel tanks, and instrument panels within a short distance (half a mile) from the assembly plant. Suppliers will perform sub-assembly and in-line sequencing of components that will reduce component pick up at the main assembly plant to a single location. Proximity of supplier work eliminates shipping costs, expensive containers, and shifts more of the burden of testing to the supplier. The OEM has reduced its burden by exiting asset-intensive, low margin manufacturing activities.

Another concept underway is the so-called Pay-on-Production [Weber, 2003] concept being inaugurated at the new Ford assembly plant in Cologne (Germany). Under this system, the supplier will pay for and own the tooling and other production equipment, freeing some of the automaker’s assets. The automaker repays the cost through production, with payment credited as each car rolls off the assembly line. Under this system, Durr, a supplier of turnkey paint shops to the automotive industry, would not only own the means of production, but would also provide manpower for support services such as cleaning, material handling, and quality management of the paint operation.

Semiconductor Industry: This concept can also be found in the semiconductor industry where the very high fixed cost of company-owned fabrication facilities (fabs) has pushed a score of young, entrepreneurial design innovators to operate so-called fabless
semiconductor companies. These operations are completely manufacturing-asset free and the industry forecast [Sheldon, 2002] is that by 2010, half of all IC revenue will come from fabless operations—pure play fabless companies and fabless operations of integrated device manufacturers (IDMs) and system houses. These fabless companies have largely outperformed the traditional IDMs (e.g., Motorola, IDT, LSI Logic), which are now closer to accepting the fabless business model as a way for quick response to market changes without the heavy burden of capital expenditures.

4.2 BUNDLING OF GOODS AND SERVICES

Another reaction to the pressure of asset-intensive, low margin production of standardized goods for mass markets appears to be a turn by traditional manufacturing companies towards the so-called “bundling of goods and services” as a means to grow profitably again. Peter Drucker [Panchak, 1998] theorizes that traditional manufacturing companies will need to ultimately restructure themselves into “systems companies in which the starting point is not making the goods, but service to enable the customer to get the fullest benefit from the goods.” In other words, a shift from mass production of standardized goods to “comprehensive customer-driven service underpinned by manufactured goods.” (Panchak, 1998) Examples of this shift from standardized goods to service companies can be found in GE as a seller of “power by the hour” with assumed responsibility for maintenance, repair, and upgrade of the jet engine and power turbines; GM as a transportation service solution company; and IBM as a seller of on-demand computing.

There appears to be significant movement for traditional manufacturing industries towards this evolving trend. Arthur D. Little [Tellefsen et al., 2003] recently completed a comprehensive survey of business leaders from more than 130 medium-sized to large multinational companies in Europe, Asia-Pacific, and the Americas. One of the overriding findings extracted from the survey was the recommendation by business leaders of novel business solutions built on the combination of manufactured product core competencies with additional services that create value for customers. This approach goes beyond the conventional servicing of products. It is predicated on adding functionality, delivery performance guarantees, and capturing more of the product life cycle revenues. According to the report [Tellefsen et al., 2003], and under this model, Phillips Medical Systems realizes above half of its €6.8 billion sales from services and applications combined with its imaging equipment. Such services and applications include digital archiving, document management, on-site training, asset management, financing, consultancy, and second-hand equipment supply as well as traditional maintenance. This differentiated range of services was said to be hard to copy, and provided customer lock-in.

Other successful business model innovations contained in the report include Toyota’s BT Industries (warehouse trucks), Sulzar Pumps (oil and gas pumps), Elea Chemicals (chemicals for the pulp and paper industry), and Durr (turnkey paint shops to the automotive industry).
On this side of the Atlantic, one prominent example of this strategy is the bold and, according to some observers, risky step undertaken two years ago by S. Palmisano to turn IBM into a side-by-side partner of businesses, helping them improve marketing, planning, procurement and customer services, rather than being a mere supplier of hardware and software. Revenue from global services into 2003 was of the order of $40 billion, some 5% greater than the combined contribution from hardware and software. Competitors such as HP, Microsoft, and Computer Associates who were initially skeptical about the IBM concept have quietly joined the fray with similar initiatives.

While the ultimate outcome of this business model bet will not be known for a number of years, there certainly are enough markers already to support Drucker’s prediction that today’s product-oriented companies are destined to become a combination of manufacturing and service operations. Just like the pharmaceutical industry, they must transform themselves from pure manufacturers to product/service solution providers.

4.3 FLEXIBILITY AND MASS CUSTOMIZATION

Commenting on Henry Ford’s famous epigram “The customer can have any color as long as it’s black”, Drucker [Drucker, 1990] explains that Ford was conveying his belief that flexibility is expensive in both time and money, and the customer is not willing to pay for it. What is interesting and ironic is to compare the words of Henry Ford with those of today’s auto executives, as detailed by M. Maynard [Maynard, 2003]:

- “None of us know four years from now what the right mix (of automobile models) will be. That’s why you have to be flexible.” D.C. Cuneo, Executive Vice-President of Toyota Motor Manufacturing, North America.
- “Products are coming faster than you can blink an eye. If you don’t have flexibility now, you’re dead.” D.K. Pauley, former head of manufacturing at Chrysler.
- “People want a high degree of personalization in their cars, and flexibility is going to be the key to that.” J. Connelly, Nissan’s Senior Vice President for North American Sales.
- “We will be prepared to move with the market.” G.L. Elson, GM’s Vice President in charge of vehicle operations, commenting on flexible manufacturing systems that GM is hoping to have, to some extent, in most of its plants by 2005.

These words, articulated by some of today’s auto executives, stand in stark contrast to those of Henry Ford nearly a century ago. They are a clear indication of today’s shifting product perception by the customer and an increased desire for product customization to satisfy individual tastes and preferences. Market pressures, intense competition, shifting customer preferences, and the high cost of traditional product changeover have pushed the automobile industry to be at the forefront of innovations to acquire the flexibility required to shift away from mass production toward mass customization of products. Leading the pack is the Toyota Motor Company whose Global Body Line allows up to eight different models to be built on the same line at a substantial cost savings. This approach that is being implemented in several of its North American plants will allow
Toyota to shuffle models along the same line and shift vehicles among its North American plants. Responding to stronger market demand for its new Sienna Minivan, for example, Toyota was able to easily shift additional Sienna production to a second North American plant producing pick-ups and SUVs. Other manufacturers in Detroit and overseas are also redesigning their plants with new technology that will afford them the flexibility and product customization that the competitive market demands. This trend is also found in other industries such as the electronic, apparel, and service sectors. It is clearly an emerging response to changing customer preferences, intense global competition, and advances in technology that facilitates flexibility and customization.

The Futman Report on the Automotive Industry [Fraunhofer Institute, 2003c] gives an automotive OEM vision of car manufacturing in 2020 as follows: “Small scale factories producing 5-10,000 cars/year. The space frame and other basic parts would come from suppliers closer to the assembly factories. In the factories, components chosen by the customers are added.”

The remainder of this section will provide a brief review of some of the drivers and facilitators of mass customization and its potential benefits. It will conclude with examples of the emerging response in other industries, such as the electronics, apparel, and service sectors.

### 4.3.1 Drivers of Mass Customization

Some of the main drivers of mass customization include the customer, competition and markets, and enabling technologies. The population of customers is not expected to remain homogeneous in its perception of products. It is, instead, expected to demand products customized to individual preferences, with improved quality, delivery, performance, and service. Globalization has ushered increased competition on products with significantly shorter life cycles. Increased competition has led to a high degree of product ‘imitation’ and product ‘commoditization’ and has driven differentiation and potentially greater profit margins to be dependent on customization. It will be increasingly difficult to satisfy the level of responsiveness demanded by the customer simply by holding up inventories. Assembly-to-order will continue to be the strategy of market leaders such as Dell.

### 4.3.2 Enabling Technologies

There are a number of technologies which companies will need to master if they are to execute the strategies identified above. These enabling technologies include but are not limited to RFID, 3D scanning, agile manufacturing, and a variety of information technology tools and techniques.

RFID has already started to exert an increased push toward mass customization. One of the many roadblocks to mass customization is establishing a foolproof method of sending the appropriate commands that reflect customer specifications to the machines on the
production line. One option is a RFID that can store information (specifications) on the RFID tags attached to the material to be processed. As the product material moves along the production line, the RFID decoder reads the tag and conveys the information to the machines. The machines execute the appropriate operations on the product material according to the consumer customization preference. For example, RFID could store the paint color of automobile body parts. [Roberti, 2004]. When the body reached the automated paint shop, the tag would be read and the specified color used on the body.

3D Scanning is another technological innovation that could pave the easy adoption of mass customization. Generating machining operations for standard and pre-programmed part shapes is no longer a challenge; recognizing products in three-dimensional objects, however, is. 3D scanning could provide an answer. Using this technology, customers could scan a physical part and automatically generate an accurate 3D digital image for customized manufacturing. Toyota, Harley Davidson, and many other manufacturers worldwide have turned to this technology for mass customization and quality assurance. Being compatible with CAD/CAM standards, this technology could be integrated into existing facilities for flexibility and increased productivity.

Mass customization follows the build-to-order (BTO) model and, therefore, requires that companies possess an agile manufacturing facility. This, in turn, means that existing mass production lines must be converted to incorporate mass customization concepts. Agile manufacturing enables companies to produce in smaller lot sizes as compared to the larger lot sizes in mass production. Smaller lot sizes help companies gain scheduling flexibility and increased speed of throughput in the plant.

Information technology (IT) has given a significant boost to supply chain engineering that plays a vital role in executing the principles of mass customization. Mass customization needs a synchronized information management system among companies, suppliers, and sub-contractors, among others. Such an efficient communication network is provided through IT software packages and the Internet. A sample of such systems includes:

- Component Supplier Management (CSM): This software tool maintains a database of parts and raw materials needed for the manufacturing process. Using the CSM, companies can classify, store, and retrieve information to identify used parts that can be reused and lock in on the nearest available materials on an as-needed basis.
- Product Data Management (PDM): This software system manages all relevant product definition activities during the product lifecycle. It is primarily an electronic document and file storage vault with workflow management and bill-of-material (BOM) management capabilities.
- The Web: The Worldwide Web is probably the most highly visible enabling tool for mass customization. Used in both of its forms – the Internet and Intranet, the web provides a virtual organization of customers, companies, and strategic
partners, allowing the easy flow of data globally that is critical for mass customization.

### 4.3.3 Approaches to Mass Customization

The following is an extract from a Harvard Business Review (HBR) article by James H. Gilmore and Joseph Pine II (Gilmore and Pine, January, 1997. This article breaks down mass customization into four different approaches (Figure 4.3.1), namely:

![Diagram](Image)

**Figure 4.3.1 – Approaches to Mass Customization**

(Source: Gilmore and Pine, January 1997)

**Collaborative**

Manufacturers following the collaborative approach create channels of communication with customers to help them enunciate their needs and requirements. Then the feedback is used to create the ideal and fitting products to meet the market requirements. Collaborative customization is ideal when customers cannot easily articulate what they want and grow frustrated when forced to make a selection from various options.

**Adaptive**

This approach deals with manufacturers producing one standard product but designing the product so that users can alter it at their end. This approach is appropriate when customers want the product to perform in different ways on different occasions, and technology makes it possible for them to customize the product easily on their own.
Cosmetic approach deals with presenting a standard product differently to different customer segments. For example, a standard product can be packaged or advertised differently to make it appealing to different segments.

Transparent approach deals with manufacturers adopting a customization approach that is not visible to the customer. This approach is ideal when the market or segment requirements are easily inferred. Companies can ideally adopt either one or can combine approaches to suit their needs.

4.3.4 Industrial Acceptance
Companies representing numerous sectors have accepted the concept of mass customization, and some have already started to reap the benefits. The spectrum of companies that have implemented or are in the process of implementing this concept is highly varied. In the following section, the current and future impact of mass customization on industries is analyzed using examples from the automobile, electronics, apparel, and service industries.

Automobile Industry: Toyota
Toyota is phasing in mass customization in its production lines through a new system called Global Body Line (GBL, Figure 4.3.2). This system features a more automated, air activated jig system called the “M” jig (M for Master). Toyota Motor’s Georgetown, Kentucky, manufacturing facility was the first North American plant to implement the new system. Initially, many of Toyota’s production lines used multiple fixtures (sometimes 50 groups of three fixtures) to carry body panels to the main welding station where they were held in alignment to be welded by robots. The fixtures holding the panels were found to get in the way of the robots, making the process more difficult. Moreover, maintenance was required for all the multiple fixtures to ensure accuracy, repeatability, and overall efficiency.

Figure 4.3.2 – Toyota, Georgetown KY – Global Body Line System
The new ‘M’ jig is a single fixture that replaces the multiple fixtures. It is a single jig around which the body panels are placed. In the new system, lightweight hangers carry the auto body parts. The panels are aligned from inside by the M jig that drops in from above. This enables the robots to work in close proximity to the panels, increasing the system efficiency.

The M jig in the GBL enables twice as many robots as before to work simultaneously. The increased ease of robot movement results in more rigid body panels and better alignment, which in turn leads to a better fit of auto body parts. The single M jig costs much less than the earlier multiple fixtures and utilizes less factory space. Other observed results have included [Visnic, 2002]:

- 30% reduction in the time a vehicle spends in the body shop.
- 70% reduction in the time required to complete a major model change.
- 50% cut in the cost to add or switch models.
- 50% reduction in initial investment.
- 50% reduction in assembly line footprint.
- 50% reduction in carbon dioxide emissions due to lower energy usage.
- 50% cut in maintenance costs.

Another interesting change has been noted in the axle line of the Toyota’s Georgetown plant: fixed automated equipment has given way to more manual processes. According to Don Jackson, Vice President – Toyota Motor Manufacturing Kentucky (TMMK), the result has been increased flexibility. With automation carrying a part from station to station in the axle line, the facility lacked flexibility in responding to market needs.

Mass customization has also seeped into the auto part suppliers and contractors. For example, PPG Industries and Behr Systems have come together to develop a system that would make personalized vehicle colors a reality. They have developed the Dynamic FlexColors System that provides an increased color palette. Currently they are working on developing a Dynamic MiniBlend System to enable companies to achieve mass production levels with the Dynamic FlexColor System.

*Electronics Industry: Dell*

Dell is probably one of the best examples for revolutionizing production with mass customization. The production process in Dell (Austin, Texas) is managed electronically from the placing of the order to delivery, allowing each customized product to be tracked. When a customer orders a server and its components, the information is placed in a production queue that breaks down every subcomponent needed to build the product. The assembly area is then allotted the required inventory. Dell’s established production pipeline with its suppliers provides readily available inventory. Dell maintains only two hours of inventory, thereby reducing costs.

Dell enters component requirements based on customer specifications into a ‘traveler’ form. The product is routed to an assembler who assembles the required components
specified in the traveler form and ensures that no component is left out. The critical factors monitored by Dell to ensure optimal company performance are [Bloor, 2003]:

- **Hours of Sales Inventory**: The amount of inventory stored by the company is maintained as low as possible. In the Austin factory, the figure was a remarkable 22 hours for the servers they build, but in Dell PC plants it is more on the order of 7 hours.
- **Actual Uptime**: This refers to the actual time the company runs devoid of machine failures, lack of supplies, and so forth. This figure is maintained at 99% at most Dell plants.
- **Ship to Target**: In the server plant in Austin, the target is 5 days from order to shipment. When the factory is really humming, it can get down to 2 days.
- **Deliver to Target**: The company’s procedures require that the product be shipped to the customer on target. For business clients, care is taken not to deliver the product well before the target date to avoid storage costs for the clients.

**Apparel Industry: Nike**

Footwear giant Nike Inc. in Beaverton, Oregon, has enabled consumers to customize their sneakers through its website (nike.com). The NikeID program lets customers choose the color of the shoes and add a personal name of up to eight characters. The system also presents an image of the customized product for final confirmation by the customer. The company states it will deliver the product to the customer within two or three weeks. The personalized shoes cost just $10 more than the mass produced versions.

**Service Sector: British Airways, Ritz-Carlton, and Hotel InterContinental Hong Kong (formerly Regent Hong Kong)**

By streamlining its supply chain process, British Airways (BA) provides world-class service to its first class frequent flyers [Mok et al., 2000]. By maintaining a database of passenger needs, BA is able to deliver individualized items and services to its passengers.

Ritz-Carlton has also created a database containing the preferences of about half a million guests. The company uses this information to tailor the service provided to guests on each visit. Hotel InterContinental Hong Kong uses a similar approach for cosmetic customization by printing customer names on paper napkins and matchboxes in their dining restaurant.

### 4.4 E-COLLABORATION

Electronic collaboration – or e-collaboration – is defined as companies working together in a virtual environment using electronic technologies to achieve a common goal. The concept of collaboration is not new. Collaboration through electronic means, however, is only recently gaining industry-wide acceptance. As more and more companies in various
industries recognize the advantages of web-enabled collaborative technologies, they are quickly adopting and developing the IT infrastructure to reap the benefits of the latest advances in electronic communications.

As a growing number of companies outsource processes to remain competitive and lean, technology-enabled collaboration has taken on new importance. Globalization, reduced profit margins, increasing customer demand, the emergence of mass customization, the need to reduce time-to-market, increasingly complex designs, and various other internal and external forces are forcing companies to operate in different ways to remain globally competitive. Companies are resorting to complex matrix organization structures, joint ventures and partnerships, and other forms of value networks to address this challenge.

Such actions, however, also bring with them additional challenges associated with extended enterprises and value networks. These include issues stemming from coordination of activities, goal alignment, information-sharing, and supply chain management, to name a few. The situation is further complicated when the value network is scattered across the globe. The e-collaboration approach and associated tools have the potential to successfully address these challenges.

E-collaboration includes various activities such as knowledge management, document management, and workflow management. E-collaborative technologies enable companies to address these activities in real time. Typical areas of e-collaboration are new product design, project management, supply chain management, information-sharing (including sharing of engineering designs and technical specifications), bid management, contract negotiations, and electronic procurement.

**Benefits of E-Collaboration**

E-collaboration offers businesses a handy tool to perform tasks and operations that were originally thought to be time-consuming and costly in traditional business environments. Some of the benefits of e-collaboration already recognized by the business sector include:

- Reduced direct costs associated with the tactical-level process of decision-making by replacing face-to-face meetings with collaboration packages that allow more efficient utilization of time. By eliminating the physical commuting time incurred by different workgroup members, these groups are no longer restricted in terms of location and timing, but rather transformed into e-workgroups that can reach worldwide at any hour.

- Higher level of efficiency in business operations due to the reduction in time devoted to direct personal communications, and to the opportunity to make more resources and information available to the e-workgroup either within the same organization or across third-party vendors and joint ventures sharing the same e-collaboration platform.

- Competitive advantage by enabling more rapid and targeted responses to market changes and to new opportunities in the modern dynamic business environment. As a case in point, the Swiss-based pharmaceutical giant, Hoffman La-Roche,
established Protodigm in the United Kingdom to address the issue of knowledge management in order to speed up the process of new drug development from the traditional average of 7 years to less than 4 years and to reduce drug development costs of approximately $250 million by 30-40%. Protodigm consists of only 9 employees whose primary task is to collaborate with subcontractors around the world in the development, drug testing, and FDA approval processes through the sharing of knowledge using a common platform of e-collaboration [Coleman, 2000].

**Trends Supporting E-Collaboration**

Recent developments over the last decade have provided technological innovations that facilitate business communications and open new frontiers in communications and information sharing. These developments include the expansion of Internet services, introduction of broadband connections to the World Wide Web, the use of cellular phones, and the deployment of wireless networks, all enabling “any place at any time” connections. The use of the Internet is becoming more and more an integral part of the business process. The Internet is used in a variety of ways to facilitate and complete business operations, including e-procurement, communications with suppliers, e-management of the supply chain, and e-markets. The Gartner Group reports that e-business is expected to reach $6 trillion by 2004. [CIO.com, 2003].

Thus, it is beneficial to look at the trends in Internet use in the U.S. and assess it relative to its competitive advantage with other developed countries. According to a study by the Economist Intelligence Unit, the U.S. ranks sixth on this year's e-readiness list of 50 developed countries. E-readiness measures a nation's e-business milieu to determine how open it is to Internet-based opportunities. The United States was the undisputed leader when the e-readiness ranking first surfaced in 2000, a position it lost last year to Sweden when it fell to third place. As the United States slides further, other developed countries, particularly the four Scandinavian nations and Britain, are expected to advance. The study bases its e-readiness rankings on each country’s technology infrastructure, general business environment, degree to which e-business is being adopted by consumers and companies, social and culture conditions that influence Internet usage, and the availability of services to support e-businesses [Chabrow, 2004]. In order to regain its leading role in the e-business world, the U.S. needs to more fully exploit current e-business practices and implement new uses of the Internet for business. Among the current uses for the Internet in business are:

- **E-Procurement**: Purchases represent around 50-90% of the typical costs of businesses. E-procurement provides time-efficiencies to such options as direct orders from suppliers and lowest-bidder live auctions. It also facilitates the comparison of different packages offered by various suppliers, thereby providing potential cost savings. In one case involving Ashland Oil, it was reported that “Ashland Oil, a diversified manufacturer of energy, transportation and construction products, realized an annual savings of $30 million, eliminated
excess inventory of strategic spare parts, and cut transaction costs from $120 to $10.” [CIO.com, 2003]

- **E-marketplace:** There is a common belief among business leaders that by 2005 about 500,000 companies will be participating in business-to-business (B2B) e-marketplaces that are inter-enterprise applications capable of linking several trading buyers and sellers. The value of B2B e-commerce is, in fact, exponentially increasing as shown in Figure 4.4.1a and is expected to exceed $1.2 trillion by end of 2004.

  ![Worldwide Value B2B E-Commerce through E-Marketplaces, 1999–2004](source)

  ![Percentage of U.S. Businesses with Intranets, 1999](source)

  **Figure 4.4.1 – Online Business Trends in U.S.**
  (a) B2B e-commerce in U.S.  (b) U.S. business with Intranets
  (Source: [http://www.cio.com/sponsors/050101_sd_power.html](http://www.cio.com/sponsors/050101_sd_power.html))

- **E-management:** E-management refers to the use of the Internet and Intranets within the same enterprise or within a supply chain to communicate to others, including strategic partners, suppliers, and contractors. As such, e-management helps achieve the aim of reducing costs in the management of extended supply chains. As an example, the communications hardware and software developer Adaptec utilized e-management of supply chain with the collaboration of suppliers in Japan, Taiwan, and Hong Kong, and reported savings of $10 million in inventory costs and reduced design-to-delivery cycles. Maximizing the benefits of e-management requires a solid information technology structure that includes an extended Intranet linking both different business functions and suppliers. The use of intranets in U.S. businesses is a common practice among large entities (as shown in Figure 4.4.1b). For the most part, however, they lack integration with supply chain partners.
E-Collaboration in Manufacturing

E-business trends discussed in the previous section delineate the utilization of e-business tools in commercial and trading sectors, but do not address the manufacturing industry. The complexity of engineering work in manufacturing is a barrier in reaching the status of “e-manufacturing.” Some trends, however, are promising and may add a new frontier in the field of e-business in the U.S.

According to Tolinski [Tolinski, 2003] “Manufacturing is more than just pushing product in and out the door; it’s about launching new product lines, maintaining and upgrading equipment, and inventing and justifying new ways of doing things. Accordingly, new software applications are being combined with web-based inventory-management services to tackle specific functions.” For e-manufacturing to happen, therefore, it will require changes in manufacturing practices as well as more collaborative efforts among manufacturers, suppliers, and distribution networks – in short, throughout the whole supply chain – thereby making available in real time critical information relating to changes in forecasts. This will enable more rapid adjustments by both the supplier and in the logistical processes.

Tolinski [Tolinski, 2003] gave a detailed analysis on e-collaboration efforts in the automotive industry based on a research survey in 2000 that was conducted by the Center for Automotive Research (CAR) and the Environmental Institute of Michigan (ERIM) and sponsored by an e-business application developer, Supply-Solution Inc. The study was implemented in two steps: using focus groups to spot the major areas of concern in supply chain e-business, and conducting a full survey of 16 Tier-1 suppliers with total sales of $70.2 billion in North America. The major findings of the study indicated that:

- Tier-1 suppliers (77 %) are reducing the number of their suppliers, keeping only the ones that demonstrate proficiency in e-business technologies. The expected outcome is a reduction in the number of suppliers by around 20%.
- The expectation by Tier-1 suppliers is that the savings realized from e-business will more than compensate for the expense of implementing e-business systems. The study estimated that the overall capital spending on e-business would increase from 3% to 13% of total expenditures in two to three years. The return on investment on these expenses is expected to cover the initial costs of implementation. The current savings and the future expectations are shown in Table 4.4.1.

<table>
<thead>
<tr>
<th>E-Business Area of Investment</th>
<th>Savings Today</th>
<th>Savings When E-Business Implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering, Product design</td>
<td>4%</td>
<td>18%</td>
</tr>
<tr>
<td>Procurement</td>
<td>7%</td>
<td>16%</td>
</tr>
<tr>
<td>Quality Assurance</td>
<td>3%</td>
<td>19%</td>
</tr>
</tbody>
</table>

Table 4.4.1 – Expected Cost Reductions from E-Business
(Source: Tolinski, 2003)
Automotive industry experts predict an expansion in the use of e-business capabilities of suppliers in such areas as procurement, collaborative engineering work, production planning, and inventory management with the breakdown of each function shown in Table 4.4.2.

Tier-1 suppliers are expecting their suppliers to become more e-capable within the horizon of two years, with collaboration efforts in various business and engineering functions as shown in Table 4.4.3.

The main barriers for the implementation of e-business solutions for suppliers of Tier-1 suppliers are the cost of implementation, the lack of supporting hardware and software needed for e-business, and/or the lack of human resources capable of implementing the shift.

The main hindrances to e-business expansion by suppliers that have already implemented it are network security issues and maintenance costs.

<table>
<thead>
<tr>
<th>Application Area</th>
<th>Business Function</th>
<th>Today</th>
<th>In 2 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procurement of Production Parts</td>
<td>Electronic requests for bids/proposals</td>
<td>25%</td>
<td>76%</td>
</tr>
<tr>
<td></td>
<td>Catalog searches of supplier general catalogs</td>
<td>9%</td>
<td>45%</td>
</tr>
<tr>
<td></td>
<td>Catalog searches based on specially negotiated prices</td>
<td>3%</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td>Allow reverse auctions</td>
<td>4%</td>
<td>34%</td>
</tr>
<tr>
<td>Collaborative Engineering</td>
<td>Send, receive interoperable CAD files</td>
<td>25%</td>
<td>73%</td>
</tr>
<tr>
<td></td>
<td>Transmit ECNs, part version control and tracking</td>
<td>18%</td>
<td>72%</td>
</tr>
<tr>
<td></td>
<td>Enable joint product design</td>
<td>12%</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>Maintain a common database</td>
<td>7%</td>
<td>58%</td>
</tr>
<tr>
<td>Demand Planning and Management, or Inventory Management</td>
<td>Computer-to-computer communications between Tier-1 and supplier</td>
<td>41%</td>
<td>85%</td>
</tr>
<tr>
<td></td>
<td>Send orders and releases</td>
<td>33%</td>
<td>81%</td>
</tr>
<tr>
<td></td>
<td>Receive advance shipping notices</td>
<td>30%</td>
<td>77%</td>
</tr>
<tr>
<td></td>
<td>Track shipments in transit</td>
<td>27%</td>
<td>76%</td>
</tr>
<tr>
<td></td>
<td>Check part availability</td>
<td>0%</td>
<td>66%</td>
</tr>
<tr>
<td></td>
<td>Just-in-time</td>
<td>23%</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>Vendor-managed inventory</td>
<td>12%</td>
<td>59%</td>
</tr>
<tr>
<td></td>
<td>Computer-to-human communications: automated on Tier-1’s end</td>
<td>27%</td>
<td>51%</td>
</tr>
<tr>
<td></td>
<td>Observe supplier’s inventory of production schedules</td>
<td>0%</td>
<td>49%</td>
</tr>
<tr>
<td></td>
<td>Observe inventory or production schedules of supplier’s supplier</td>
<td>2%</td>
<td>40%</td>
</tr>
</tbody>
</table>

*Table 4.4.2 – Industry Expectations from E-Business (Percent of Supply Chain Processing Various E-Capabilities) (Source: Tolinski, 2003)*


<table>
<thead>
<tr>
<th>Capability</th>
<th>Today</th>
<th>In 2-3 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer-to-computer communications – automated on both ends</td>
<td>49%</td>
<td>78%</td>
</tr>
<tr>
<td>Computer-to-human communications – automated on one end</td>
<td>29%</td>
<td>56%</td>
</tr>
<tr>
<td>CAD interoperability or similar CAD systems</td>
<td>28%</td>
<td>63%</td>
</tr>
<tr>
<td>Production planning</td>
<td>23%</td>
<td>70%</td>
</tr>
<tr>
<td>Logistics/order tracking</td>
<td>18%</td>
<td>66%</td>
</tr>
<tr>
<td>Integration between data sent to suppliers and their internal systems</td>
<td>15%</td>
<td>59%</td>
</tr>
<tr>
<td>Catalog pricing</td>
<td>15%</td>
<td>54%</td>
</tr>
<tr>
<td>Finished goods inventory</td>
<td>14%</td>
<td>63%</td>
</tr>
</tbody>
</table>

Table 4.4.3 – Estimated Percentage of Suppliers Capable in Various Areas of E-Business
(Source: Tolinski, 2003)

Roadblocks for the Implementation of E-Collaboration

E-collaboration represents a new frontier in the e-business world—one step higher than simple direct communication among different parts of a business stream. Implementation roadblocks continue to exist due to:

- Financial Burden: The implementation of e-collaboration software requires a budget of several thousands of dollars and that amount can increase significantly depending on the number of seats needed to access system capabilities and features to be included. Added to this is the cost of hardware and other technology infrastructure within the enterprise to support the e-collaboration system.
- Security Concerns: The network security is a major concern in the competitive business environment.
- Lack of Standardization. The deployment of various proprietary system platforms is one of the major roadblocks for e-collaboration as it necessitates converting e-collaboration software from one platform to another. Currently, however, some efforts are being made to drive standards. These include:
  - Documentum: Documentum (http://www.documentum.com), a commercially available Enterprise Content Management (ECM) application that provides capabilities such as e-room for more collaborative efforts like document exchange, CAD file previews, and project management. In an important step forward for standardization. Documentum released the following news at an October 27, 2003 press conference: “Documentum (NASDAQ: DCTM), the leading provider of Enterprise Content Management (ECM) software, today announced that the U.S. Environmental Protection Agency (EPA) has selected the Documentum ECM platform as the standard for records management and document management applications throughout the entire agency.“ [Documentum.com. 2003].
  - Interoperability of Engineering Designs: The exchange of engineering CAD files is another concern of the manufacturing industry because of the number
of different packages in use by different parties involved in the design and procurement of the components that are needed to produce the design. Converting from one CAD package to another often leads to a loss of some of the details with the part geometry being transferred without any of the feature details and constraints. The regeneration of drawings from the converted file is time-consuming and costly in terms of labor, and the process increases the length of the product design life cycle. That said, there are efforts being made to design collaborative packages that allow interoperability and thereby reduce the design cycle time. One of the most promising packages is offered by Proficiency, considered one of the leaders in CAD interoperability software. Proficiency software utilizes feature-based file transformation that allows parameters to be attached to geometric features [Proficiency.com, 2004].

- RosettaNet: RosettaNet [RosettaNet.org, 2004] is a network of IT, electronics, and semiconductor manufacturing coalitions working towards creating a common platform for communications among industry professionals. “RosettaNet is a consortium of major Information Technology, Electronic Components, Semiconductor Manufacturing, Telecommunications and Logistics companies working to create and implement industry-wide, open e-business process standards. These standards form a common e-business language, aligning processes between supply chain partners on a global basis. RosettaNet is a subsidiary of the Uniform Code Council, Inc. (UCC). Developed by means of an industry-wide partnership, RosettaNet’s standards address the Information Technology (IT), Electronic Components (EC) and Semiconductor Manufacturing (SM) supply chain, including manufacturers, distributors, resellers, shippers and end users.” [RosettaNet.org, 2004]

### 4.5 ECOLOGICAL DESIGN OF PRODUCTS

The manufacturing industry is one of the biggest consumer of the planet’s resources and also a producer of waste which interacts with earth’s air, water and soil. Although 100% elimination of harmful materials from the waste may not be feasible in the near future, the goal of many business establishments is to bring down this harmful effect on the environment to levels sustainable by the planet. Increased ecological awareness coupled with the legislative actions has driven companies to pursue economical means to design and manufacture.

One of the biggest steps towards this goal is to design the product for minimized impact on nature. Designers and manufacturers set out to chart the interaction of their product with the environment in all of its life stages, namely production, usage and disposal. Efforts are undertaken to incorporate the 3 ‘R’s – reduce, reuse and recycle, into the product design. This concept of design is called Ecological Design, or Green Design. This strategy results in eco-friendly performance by the product and also minimizes costs for industry.
Life Cycle Assessment (LCA) also referred to as Product Lifecycle Management (PLM) is emerging as the key for many manufacturers for ecological design. Some sample expert opinions on LCA are listed below [Teresko, 2004]:

- According to the University of Michigan's PLM Development Consortium, "PLM is an integrated, information driven approach to all aspects of a product’s life from its design inception, through its manufacture, deployment and maintenance and culminating in its removal from service and final disposal." says Michael W. Grieves, the consortium's co-director.
- "PLM is the integration of business systems to manage a product's lifecycle." "In product development, projects like PLM have helped spare a billion dollars of cost over the past three years," says GM's Terry S. Kline, global product development process information officer. An even greater benefit of the concept was identified in dramatically reducing the time-to-market, the lapsed time from idea to saleable product. Kline says PLM's role in reducing that measure from 48 months to 18 has helped the company gain market share.
- "In a business sense, the data and information provided by PLM needs to be regarded as being crucial in the same sense that knowledge of inventory levels has always viewed as critical. Inaccessible information has become as much of a disadvantage as inaccessible inventory," says Ron Watson, global product data manager, ITT Industries, Upper Saddle River, N.J

In the following section, the concept of LCA is elaborated and its impact on the manufacturing industry is portrayed using some of the biggest industries like automobiles and electronics.

### 4.5.1 Life Cycle Assessment

LCA – Life Cycle Assessment or Life Cycle Analysis – is an integrated “cradle to grave” approach to assess the environmental performance of products and services. "Cradle-to-grave" begins with the gathering of raw materials from the earth to create the product and ends at the point when all materials are returned to the earth. The term "life cycle" refers to the major activities in the course of the product’s life span (Figure 4.5.1) from its manufacture, use, maintenance to its final disposal, including the raw material acquisition required to manufacture the product. A product’s environmental impact at each of its life stages is assessed and predicted, and the product is designed to reduce harmful effects.

![Figure 4.5.1: Life Cycle Stages](Image)

*Source: US – EPA, 1993*
An LCA helps decision-makers select the product or process that results in the least impact to the environment. This information can be used with other factors, such as cost and performance data, to select a product or process. LCA data identifies the transfer of environmental impacts from one medium to another (e.g., eliminating air emissions by creating a wastewater effluent instead) and/or from one life cycle stage to another (e.g., from use and reuse of the product to the raw material acquisition phase).

The impact of LCA on an industry would, in general, be in the areas of:

- Product improvement
- Product design
- Formulation of company policy
- Product information
- Use in negotiations
- Formulation of marketing strategies

Many industries have realized the need for LCA as evidenced by the activities executed by major manufacturing companies. The following section examines the initiatives of Toyota and Panasonic to maximize efficiency through ecological design.

4.5.2 Automobile Industry: Toyota

On June 16, 2003, Toyota Motor Corporation (TMC) unveiled a comprehensive environmental impact assessment system, Eco-VAS (Eco-Vehicle Assessment System), based on LCA (Figure 4.5.2). This program allows a systematic assessment of the burden of the vehicle on the environment throughout the vehicle development process that results from its production, use, and disposal. The program’s main features include [LCA Eco-VAS main points, Toyota, 2004]:

- Setting environmental impact reduction targets for a product.
- Assessing the environmental impact of fuel efficiency, emissions, and noise during vehicle use, the disposal recovery rate, the reduction of substances of environmental concern, and CO₂ emissions throughout the life cycle.
• Using a computer network (established in 2004) to check the status of target achievement, continually confirm results, and obtain feedback during the entire development process.

TMC proposes to implement the Eco-VAS system beginning in 2005 and also execute a comprehensive environmental impact assessment during the planning stage for all its newly developed vehicles.

**Manufacturing Phase:**

In 2002, Toyota conducted LCA on the manufacturing of old and new style hydraulic fittings used in forklift trucks (Figure 4.5.3). The amount of pollution released into the air during the manufacturing process was assessed.

Toyota Industries used both published and database values from LCA software. The assessment was carried out using the following three methods:
- Method A: Assessment based on survey of actual energy consumption.
- Method B: Assessment based on functional unit* used for household appliances.
- Method C: Assessment based on functional unit used for automotive parts.
* Functional unit: CO₂ emissions per material mass in a production process.

**Assessment Results:**

The greatest difference between the new and old products was noticed when using Method A assessment. It resulted in a 21% reduction in emission compared to the old product (Figure 4.5.4). Methods B and C resulted in smaller differences (11% and 15%, respectively) despite the process change from forging to bending which would significantly reduce the overall energy consumed in manufacturing the new product.
**Figure 4.5.3 – LCA – Comparison of Manufacturing Processes**  
(Source: Toyota Industries-Environment)

**Figure 4.5.4 – Comparison of Emissions**  
(Source: Toyota Industries-Environment)
**Product Usage Phase:**
Efforts in this stage are concentrated on reducing emissions and improving fuel efficiency.

*Gas emissions:* Through optimal usage of catalytic converter systems, Toyota has achieved a steady reduction in exhaust engines. (Figure 4.5.5)

*Fuel Efficiency:* The graph on Fuel Efficiency in Figure 4.5.5 shows the fuel efficiency of the Starlet/Vitz model. Toyota has realized an improvement in fuel economy by adopting innovative technologies like 4-valve engines, Super ECT (Electronic Control Transmission), and VVT (Variable Valve Timing). The adoption of the intelligent idling stop system, has enabled Toyota achieve a 70% improvement in fuel efficiency compared to 10 years ago.

The third graph in Figure 4.5.5 shows how Toyota's vehicles are meeting 2010 fuel efficiency values in each weight category. In six of the eight categories, Toyota was already in line with the 2010 fuel efficiency standards by fiscal year 2002, and all eight categories are expected to be in line by 2005.

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![Figure 4.5.5 – Impact of LCA on Product Usage](source: Toyota’s Fifth Environmental Forum)
**Recycling Phase:**

Toyota has been developing easy-to-recycle vehicles and body parts in accordance with the Automobile Recycling Law. Focus is provided to the following four key points:

1. Adoption of environmentally considerate technologies.
2. Easy dismantling
3. Reduction of harmful substances.
4. Reduction of polyvinyl chloride (PVC) resin usage

**Shortening the Necessary Dismantling Time by 30%:**

Toyota has employed innovative dismantling techniques in the new Raum model for easy dismantling of the structure. This shortened the dismantling time by 30%, compared to the previous model. Toyota effected improvements in fluid removal and removal of large resin parts. For the above purposes, Toyota adopted the following specific steps:

1. Structures that allow bonded areas to come apart when pulled hard
2. Use of clips instead of screws for securing components whenever possible
3. Parts integration
4. Avoidance of composite materials

**Development and Adoption of the “Easy to Dismantle Mark”**

A new “Easy to Dismantle Mark” is added to vehicle parts clearly indicating certain points that assist in initial dismantling (Figure 4.5.6), such as the positions at which large resin parts can be easily separated and the locations at which holes can be drilled for removing fuel.

**Reduction in Substances of Environment Concern:**

Toyota is working to reduce certain banned substances of environmental concern in its new Raum model.

1. **Lead:** Lead has been eliminated from wire harness shields and fuel tanks. Through its voluntary activities, Toyota has reduced the lead usage to less than 1/10 of the 1996 levels, which was to be met by 2006 according to Japanese automobile industry’s voluntary goal (reduction to 1/4 of the previous model or 123g/unit).
2. **Mercury:** Toyota has achieved the voluntary goals set out by the Japanese automobile industry prohibiting usage of mercury in parts other than LCD displays of navigation systems, etc. from 2004.
3. **Cadmium:** Toyota has abolished the use of cadmium in fog lights and turn signal lamp bulbs.
4. **Hexavalent chromium:** Toyota began using alternative materials in some nuts and bolts, etc.
Figure 4.5.6 – Easy-to-Dismantle Vehicle Structure in the New Raum System
(Source: Toyota - Toward Enhanced Recyclable Vehicle Design)

Environmentally Friendly Materials:

Toyota has stopped PVC resin usage in some wire harness shields. In addition, the usage of PVC in the entire vehicle has been reduced to 1/4 of the previous model. Toyota has adopted materials like Eco-plastic (Figure 4.5.7) and other recycled materials with little environmental impact. According to LCA results, usage of recycled materials has reduced CO₂ emissions by 52% compared to newer materials.
4.5.3 Electronic Industry – Panasonic

Manufacturing Phase

Lead-free solders: Initiatives that were taken by Panasonic to introduce lead-free solders to all of its products worldwide were completed by March 2003. However, there are exceptions to some of the purchased units and products manufactured for other companies.

Natural Fluid (HC Refrigerator): CFCs that are detrimental to the ozone layer have been eliminated from refrigerators. The HC refrigerator uses no CFC refrigerant or foam insulation material. By using a high performance vacuum insulation material, Panasonic has attained Japan’s 2004 energy savings target by 220%.

Heat Pump Water Using Natural Refrigerant: Heating water consumes 1/3 of household energy. Panasonic’s new water heater utilizes a heat pump that uses CO\textsubscript{2} as refrigerant. Its primary energy efficiency has reached 114%, and CO\textsubscript{2} emissions are only half the amount emitted from a gas water heater.

Panasonic is also striving to reduce the use of halogenated plastics, which are used in the manufacture of coverings for electric wires and product cabinets. These plastics were initially used for their fire resistant properties. Due to the possible emission of harmful gases when incinerated, they have been replaced.
Usage Phase

**Intelligent Power Device (IPD):** Panasonic has focused considerable attention in recent years to standby power consumption as an indicator of energy conservation performance of electrical products. Standby power consumption takes place at the power unit of an appliance, typically an AC adapter.

Conventional electric power supplies are energy efficient at their rated operation levels. Current supplied to a machine in standby mode is only weak current and is wasted. Through the use of an advanced circuitry called 3-Terminal Intelligent Power Devices (IPDs) (Figure 4.5.8), Panasonic has achieved some considerable energy savings. The new built-in control function detects the standby mode and automatically cuts down the electricity consumption. IPD usage in power supplies has resulted in the reduction of power consumption by about 81% compared with conventional models. The IPDs also represent a resource and space efficient chip configuration.

Disposal Phase

**Personal Computers:** Japan’s Minister for Environment has designated Panasonic as an operator of industrial waste hauling and disposal. In 2001 and 2002, 2700 and 3000 units were collected respectively. The rate of recycling was approximately 20% for notebook PCs and 70% for desktops.

**Home Appliances:** Panasonic has developed an energy efficient decentralized recycling system for home appliances (Figure 4.5.9). As specified by Japan’s Law for recycling of special kinds of home appliances – air conditioners, TV, refrigerators and washing machines,
Panasonic is working on the collection and recycling of these appliances through 27 recycling centers and 190 designated collection points. Recycled products increased by about 20% to 2.11 million units in 2003 compared to 1.76 million in 2001.

5. SUMMARY OF KEY FINDINGS AND SME CHALLENGES

The objective of this final section of the report is to summarize key findings resulting from the prospective evaluations carried out in the preceding sections. These findings are organized under a reduced set of headings including Demographics, Globalization, Ecological Awareness, Technology and Business Strategy and Practice. This is then followed by a final section which attempts to identify key challenges to small manufacturing enterprises (SMEs).

5.1 SUMMARY OF KEY FINDINGS

**Demographics:** Changes in the size, composition and education aptitude of the workforce are expected to pose a significant challenge to the future of manufacturing. A reduced rate of increase in the workforce, “graying” of the workforce due to the baby boom generation and a persistent or deteriorating skills gap are the main concerns. They will affect the way companies hire, train, retain and compensate their future workforce. The mix and demand for goods and services is also expected to be affected by demographic changes with increased demand for health care goods as well as for products designed for safety, comfort and assisted use.

**Globalization:** Trade liberalization beginning in the 1970’s and exploding in the 1990’s is allowing multinational corporations, transnational corporations and even small national companies to move manufacturing production to where they can take advantage of factors including: low wages and limited obligations such as pensions and health care; financing subsidies and loan guarantees offered by foreign governments; emerging high technology countries; lower taxation and regulatory constraints; closeness to the markets where the goods are sold; lower exposure to exchange rates and easing of trade friction. This dynamic allocation and re-allocation of manufacturing production to locations that provide a competitive advantage to the firm are expected to continue in the future in spite of labor and political calls for protection of local manufacturing jobs and the problems posed for low skilled workers. Competition from low wage producers as well as that from emerging high technology exporters is also expected to continue to exert pressure on U.S. manufacturing jobs. The prospects are not good for low technology U.S. manufacturing jobs that are easily imitated by foreign low wage producers and when proximity to the US market is not a disadvantage. High technology U.S. manufacturing jobs will come under increased challenge from foreign high technology exporters who have made significant investments in infrastructure, education, R&D and industrial policy to attract high technology manufacturing.
Ecological Awareness: The manufacturing industry is a major consumer of resources and a producer of goods and waste that interact with the environment. Spectacular market failures in the past including mercury, PCBs and other toxic contamination of the environment and the use of harmful substances such as asbestos in manufactured goods have increased ecological awareness and spawned a number of regulatory and legislative actions; these regulations already impose a heavy burden on manufacturing firms and more regulatory pressure is expected in the future, particularly from large trading blocs such as the EU. SMEs will be most vulnerable because of limited resources and uncontrollable pressure through the supply chain. Proactive companies will seek to use regulatory constraints as a competitive advantage by developing innovative ecologically tolerant product/process strategies. SMEs with fewer R&D resources, smaller market share or a less progressive approach risk losing access to markets and customers.

Technology: Throughout the last two centuries technological innovations have had a profound and disruptive effect on the manufacturing of this country and the world. Technology is expected to continue to be a major driver of the future of manufacturing. Technological drivers such as nanotechnology, biotechnology, hydrogen fuel cell technology and Radio Frequency Identification Tags are attracting significant interest and investment from industrialized countries as they are seen to be the potential drivers of future manufacturing jobs.

Business Strategy:
Shedding of Physical Assets: Traditional product manufacturers with mature technologies subject to increased global competition, over-capacity, price-pressure and other market challenges will seek to exit asset-intensive, low margin activities. This scenario will seek to replace company-owned manufacturing with outside supply chain management while investing in intangible assets such as knowledge and brands. The trend is clearly manifest in aerospace, automobile and semiconductor industries and creates both challenges and opportunities for SMEs.

Bundling of Goods and Services: As Drucker observed, companies will look to restructure themselves into “Systems Companies in which the starting point is not making the goods, but service to enable the customer to get the fullest benefit from the goods.” (Panchak, 1998) Examples include traditional automobile companies as transportation services companies; makers of jet engines and power turbines as sellers of “power by the hour”; and computer manufacturers as sellers of “on demand” computing. This approach goes beyond conventional servicing of products. It is predicated on adding functionality, delivery performance guarantees and capturing more of the product life cycle revenue.

Flexibility and Mass Customization: Nearly a century ago, Henry Ford is reported to have said that “The customer can have any color as long as it is black.” Today and in the future, market pressures, intense competition, shifting customer preferences and the high cost of traditional product changeover will push industry to be at the forefront of innovation to acquire the flexibility required to shift away from mass production towards mass customization of products.
E-Collaboration: Globalization, increased competition, shifting customer preferences, increasingly complex mass customized products and other market forces are forcing companies to resort to complex matrix organization structures, joint ventures, partnerships and other forms of value networks. These actions in turn bring with them additional challenges such as coordination of activities, goal alignment, information sharing, collaborative designs and supply chain management. E-Collaboration and associated software and hardware tools will offer businesses a way to perform some of these tasks efficiently in order to gain competitive advantage.

5.2 KEY CHALLENGES FOR SMEs

The purpose of this final section of the report is to suggest a framework of key challenges for SMEs with respect to the future. Michael Tracey [Tracey, 1975] premised predictions of the future as follows: “In attempting to foresee the future we all suffer from blindness, astigmatism and inadequate color correction; even worse, we are not aware of the precise nature of our visual handicap, only that they must be there and are probably acute.” Patton [Patton, 1993] proposed evaluation and futuring as the two pathways to a prospective exercise. Evaluation involves a rigorous assessment of current conditions, strengths and shortcomings. Futuring considers new directions in light of major trends, changed perceptions and needs. It is not so much about predictions but rather about getting prepared for new possibilities. The suggested challenges involve some areas and functions of the typical firm such as Human Resources, Customers and Markets, Technology Development, Access and Awareness, Alliances and Networks. The format and content of some of the challenges are heavily influenced by some of the recommendations given by Howard Partners Pty and the Australian Centre for Innovation and International Competitiveness [Howard et al., 2001].

5.2.1 CUSTOMERS AND MARKETS

Evaluation and Futuring

<table>
<thead>
<tr>
<th>Today</th>
<th>10-15 years from now</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which customers are you serving today?</td>
<td>Which customers will you be serving in the future</td>
</tr>
<tr>
<td>What channels do you use to reach customers now?</td>
<td>What channels will you use to reach customers in the future?</td>
</tr>
<tr>
<td>What means do you use to lock in customers now?</td>
<td>What means will you use to lock in customers in the future?</td>
</tr>
<tr>
<td>In what end product markets do you participate today?</td>
<td>In what end product markets will you participate in the future?</td>
</tr>
</tbody>
</table>
Key Futuring Considerations

- Product perception is evolving toward modularized, ecologically tolerant and customized products designed to serve global markets.
- Demographic trends will favor an aging and affluent group with preference for assisted use of goods, increased service and healthcare products.
- The proliferations of the Internet and Electronic Commerce have increased consumer awareness of a growing range of products and services worldwide.
- Globalization and the proliferation of free trade agreements enable businesses to access new markets and customers. They will bring about increased competition and opportunities.

Challenges for SMEs

- New product development should consider
  - Ecological awareness for competitive advantage and market access
  - Mass customization potential for differentiation and higher profit margins
  - Demographic trends and an aging population
  - Inclusion of services with goods for differentiation and customer lock in
  - Vulnerability to global competition and low wage producers
- Global strategy for access to new markets should
  - Target companies that manufacture in the U.S. and exploit the competitive advantage of proximity, access and privileged market and product knowledge
  - Export or sell to companies with a strong export focus by identifying and adopting best business practices of successful exporters and seeking export guidance from available government and business advisory services
- Leverage the Internet and E-Commerce for customer access.

5.2.2 HUMAN RESOURCES

Evaluation and Futuring

<table>
<thead>
<tr>
<th>Today</th>
<th>15 years from now</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the demographic profile of your workforce today?</td>
<td>What will the demographic profile of your workforce look like in the future?</td>
</tr>
<tr>
<td>What skills and capabilities make your workforce unique today?</td>
<td>What skills and capabilities will make your workforce unique tomorrow?</td>
</tr>
<tr>
<td>What means do you use to retain your best people today?</td>
<td>What means will you use to retain your best people in the future?</td>
</tr>
<tr>
<td>What kind of training and life long learning programs do you use today for your workforce?</td>
<td>What kind of training and life long learning programs will your workforce need in the future?</td>
</tr>
</tbody>
</table>
Key Futuring Considerations

- Expected decline in the growth rate of the U.S. workforce may create labor shortages and increased competition for skilled workers.
- Demographic trends will cause greater participation of people 55 and older in the workforce.
- Demographic trends will also bring in greater participation of women and minorities in the workforce.
- Expected persistence of a skills gap in the workforce.

Challenges for SMEs

- Develop innovative strategies to retain an older workforce by
  - Rethinking early retirement packages
  - Developing innovative health and benefit packages
  - Rethinking compensation and work schedules
- Develop innovative hiring strategies to attract women and minorities
- Develop innovative learning and training programs
- Increase the use of innovative automation to counter labor shortages and business cycle fluctuations

5.2.3 ALLIANCES AND NETWORKS

Evaluation and Futuring

<table>
<thead>
<tr>
<th>Today</th>
<th>10-15 years from now</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the basis of your competitive advantage today?</td>
<td>What will be the basis of your competitive advantage in the future?</td>
</tr>
<tr>
<td>What are the gaps and shortcomings in your capability today?</td>
<td>What will be the gaps and shortcomings in your capability in the future?</td>
</tr>
<tr>
<td>Who are your partners today and what value do they add to your business?</td>
<td>What kind of cooperative alliances will you need in the future and how will they add value to your business model?</td>
</tr>
</tbody>
</table>

Key Futuring Considerations

- Large companies will shed physical assets and exit asset intensive, low margin activities creating new opportunities for nimble small businesses and alliances of such businesses.
- Rapid rate of technological change and high risk of obsolescence due to global competition make alliances and networks highly likely and desirable.
- Cooperative strategies have the potential to help small firms acquire required resources, access new technology and markets, and spread the risk over several partners.
Challenges for SMEs

- Identify key resources and core competencies that would attract partnerships and alliances.
- Identify shortcomings in capability that would benefit from partnerships and alliances.
- Seek out, evaluate and select potential partners.
- Determine the most suitable type of cooperative alliance for your business. Consider joint programs/contracts, joint ventures, minority equity investments, licensing agreements and other types.
- Develop and implement a plan that defines clear objectives, responsibilities, accountability, performance measures and reporting methods, protection of intellectual property, financial and legal issues, periodic reviews and strategy sessions.

5.2.4 TECHNOLOGY DEVELOPMENT, ACCESS AND AWARENESS

Evaluation and Futuring

<table>
<thead>
<tr>
<th>Today</th>
<th>10-15 years from now</th>
</tr>
</thead>
<tbody>
<tr>
<td>- What is the basis of your technological advantage today?</td>
<td>- What will be the basis of your technological advantage in the future?</td>
</tr>
<tr>
<td>- What channels and methods do you use to acquire new technology now?</td>
<td>- What channels and methods will you use to acquire technology in the future?</td>
</tr>
<tr>
<td>- What channels do you use to stay aware of new technological developments now?</td>
<td>- What channels will you use to stay aware of new technological developments in the future?</td>
</tr>
<tr>
<td>- What are some of the gaps and vulnerabilities in your technological capabilities today?</td>
<td>- What will be the gaps and vulnerabilities in your technological capabilities in the future?</td>
</tr>
</tbody>
</table>

Key Futuring Considerations

- An increasing amount of technology that provided SMEs with a competitive advantage in the past is now widely accessible to foreign competition, which in some cases enjoys a considerable labor cost advantage. More nations all over the globe have invested and built significant technological infrastructure, R&D capability and are now competitors for even the most advanced manufacturing technologies.
- High technology and particularly disruptive technologies will be a major driver of future manufacturing.
- SMEs need to acquire the means for new technology awareness, development and acquisition.

Challenges for SMEs

- Develop strategies to identify, invest in and acquire core technologies.
- Consider cooperative agreements with research centers at universities, technology transfer offices, government laboratories and government programs for technology awareness and diffusion.
- Consider a presence next to successful technological clusters in your field or with technology related to your products and markets.
- Consider cooperative alliances with other firms to access new technology.
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