INDUSTRY STUDIES 2000

Advanced Manufacturing

ABSTRACT:

Advanced manufacturing is the making of a better product suitable for more immediate use at a cheaper cost. It is a critical aspect of many industrial sectors and an essential component of U.S. national defense. Manufacturers must cope with rapid changes in markets—including workforce, process, and technology changes—while operating in a dynamic, competitive, and global environment. They deal with this environment by selectively focusing their resources and efforts to sustain competitive advantage. They also pursue partnerships for research and development, for workforce enhancements, and for supply and production functions that they cannot efficiently accomplish themselves. These relationships create dependencies that can impede defense mobilization, however. The government can play a meaningful role in dealing with potential mobilization shortfalls and other major challenges facing the nation's domestic manufacturing sector.

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INTRODUCTION:

A robust domestic manufacturing sector is a major contributor to U.S. predominance in today's global environment. It is a cornerstone of both the economic prosperity and the strong national defense of the United States. As a significant source of competitive advantage in a changing world, manufacturing must constantly advance.

Advanced manufacturing has a dynamic role in national and international economies and cultures. In addition, it has an important role in the support of national security. The U.S. manufacturing sector currently meets the country's national security requirements by providing superior defense products for the nation's military.

U.S. manufacturers are excelling in a dynamic, global, and interdependent environment by getting their products to the marketplace better, faster, and cheaper. They are achieving competitive advantage through keen insight into the complex characteristics of the changing marketplace and the implementation of initiatives that achieve an advanced level of manufacturing. The key enabling factors identified in this study fall into four categories: workforce, processes, technology, and systems integration. Major initiatives being implemented in the United States include preparation or the workforce for the 21st century, the creative use of international and domestic partnerships, and the application of enterprise resource planning (ERP). All have a particularly broad impact on the potential advancement of manufacturing.

The study identified some manufacturing sector weaknesses and recommended actions to meet these challenges. Weaknesses include a shortage of skilled workers, a limited surge capability to meet security requirements, and vulnerabilities to infrastructure attack. Businesses will continue to respond to these challenges by focusing their efforts and resources on establishing and maintaining core competencies. The federal government must contribute by taking steps to strengthen the workforce, expand investment in basic research and development (R&D), ensure a surge capability in areas critical to national security, and improve Internet security.

ADVANCED MANUFACTURING DEFINED

Manufacturing has been described as making "a product suitable for use . . . from raw materials by hand or by machinery . . . according to an organized plan and with a division of labor."[i] This description defines manufacturing first by its objective, then by its resources, and finally by its processes. It is not product-, industry-, or market-specific.

This definition is limiting. For example, it specifically mentions the use of raw materials. Yet, many manufacturers assemble components into higher assemblies or end products; their materials are not raw. Some of their products then flow to other manufacturers or to retailers and end users. The value chain concept—that the creation of product value occurs along a chain from design and development through components and subsystems to customers—is alive and operational.

This definition of manufacturing also does not make clear what makes manufacturing "advanced." For example, its precepts can support the use of versatile workforces, integrated planning processes, flexible manufacturing cells, or advanced materials as bases for declaring manufacturing to be advanced. In practice, these enabling factors all have an association with advanced manufacturing. There is a question, however, about which or how many of these or other workforce, process, or technology initiatives would be the minimum essential to declare a manufacturing enterprise "advanced." Few world-class manufacturers have adopted more than a handful of advanced processes and procedures.

A simple but meaningful definition of advanced manufacturing that is consistent with its observed practice can be derived from the value chain concept, which suggests that advanced manufacturing may be most appropriately defined through its objective, or results; *advanced manufacturing is the making of a better product suitable for more immediate use at less cost*.

The key is the attainment of better, faster, and cheaper results, which are fundamental to a manufacturer's competitive advantage. Because performance, schedule, and cost are interdependent, manufacturing systems must truly advance to stand out in each of these areas. A change in a manufacturing system that is less than true advancement yields improvement in only one or two of these areas, not all three.

CURRENT CONDITION

Manufacturing advancements capitalize on workforce, process, and technology improvements. These advancements occur within industrial, national, and international contexts.

Manufacturing's Contexts

Economically, U.S. manufacturing is healthy. Its profit margins have returned to the neighborhood of 8 percent, after a dip in the early 1990s to approximately 1 percent. Other U.S. economic sectors have generated 6 jobs for every 10 jobs generated in manufacturing, far stronger than the 2:17 ratio of jobs generated in the services sector. Employment in U.S. manufacturing has stabilized at approximately 18 million jobs, even as the output grows. The annual productivity growth rate is approximately 5 percent, nearly double the average economic growth rate. Manufacturing accounts for about 29 percent of U.S. economic growth.

The United States is outpacing its overseas rivals in industrial growth. While contributing 22.9 percent to the U.S. gross domestic product (GDP), manufacturing contributed 27.3 percent to U.S. total economic output and furnished 62 percent of U.S. exports. Exports provided 20 percent of manufacturing jobs and 30 percent of U.S. manufacturing job growth. Small firms contributed better than 90 percent of

manufacturing exports.[ii]

In a global environment that includes integrated and international market, production, supply, and support systems, advanced manufacturers continue to accelerate product design, decrease machine set-up times, consolidate manufacturing steps, reduce raw material waste, and improve process planning and control. These advancements improve manufacturing efficiency and productivity. The net economic effect is the erosion of price differentiation in favor of a greater reliance on product differentiation for competitive advantage. Manufacturers repeatedly cite name recognition for quality products at competitive prices as fundamental to long-term manufacturing success. Manufacturers must meet international standards, such as those established by the International Organization for Standardization (ISO) for universally recognized standards of quality assurance (e.g., ISO 9000), and be cost-efficient to compete effectively in today's global market. To achieve both price and product differentiation, manufacturers are seeking new workforce practices, new processes, and new technology.

To deal with increased global competition, the European Union (EU) is seeking industry consolidations, aiming to strengthen its competitive advantages through internal efficiency improvements. As a result, some companies outside the EU have become concerned about sustaining business with EU strategic partners because of the potential loss of value chain integrity. Similarly, several global manufacturers have become concerned about access to U.S. technology, but U.S. manufacturers do not appear to be concerned about access to foreign technology. Several manufacturers were also concerned with diminishing numbers of manufacturing suppliers, especially in dynamic and low-quantity markets.

Today's intense globalization accelerates the diffusion of the value chain across international boundaries. Some countries are experiencing unprecedented interest and investment in manufacturing. For example, Hungary has received more than $23 billion in foreign investment since its return to capitalism after the collapse of the Warsaw Pact.[iii]

Environmental concerns and regulations also affect manufacturing practices. Manufacturers are preparing to standardize environmental practices under ISO 14000, which addresses companies' systems for managing operations that have an impact on the environment.

Along with these changes, the U.S. Department of Defense has traded its traditional lead in research and product development for an alignment to the cost-efficient research and production practices of the private sector.

Advanced Manufacturing's Enabling Factors

Manufacturing decisions to improve workforce capabilities, change processes, adopt technology, and scale production capacity all remain grounded in return-on-investment (ROI) calculations.

Workforce. Available, skilled, and affordable workforces remain key factors in deciding manufacturing locations and investments. Declining unemployment and the aging of workforces, both here and abroad, make it necessary to address availability. Their cultural and national contexts, as seen through issues like loyalty and lifetime employment, family ties and mobility, gender roles, and local wage levels and compensation, all affect workforce availability.

Skilled labor is a tried and consistent source of process flexibility. Generally, a U.S. company spends 2–5 percent of its payroll on education and training, while 77 percent of that training is accomplished on the job.[iv] Although there are some local partnerships for education, most manufacturers seem to be chafing under the cost burden of education and training because labor affordability remains a key to cost-effective competition.

Processes. The more variation or complexity in a product or process, the more likely the manufacturer is to remain close to its core competencies (i.e., its proven areas of expertise). Other competencies are sought from strategic partners. This approach limits the scope of local planning and control activities to manageable levels of complexity, while providing enterprise flexibility.

Total conversion to advanced manufacturing tooling and processes rarely occurs on one line. When faced with resource constraints

manufacturers may selectively adopt enabling technologies or processes. Some manufacturers have experienced complications, however, with selective introductions. In one case, the ramp-ups and ramp-downs for flexible product changes were occurring in just-in-time control processes, complicating inventory management.

Some advanced manufacturers are attaining mass customization. They typically maximize component commonality for available economies of scale, then use variations of key components in system assembly to customize their product.

There is movement toward distributed manufacturing, but on an economy-of-scale decision basis. One company develops a factory template and then exactly duplicates this design in new locations as additional capacity is needed.

Quality control covers a tailored range of alternatives that include closed-loop quality assurance procedures to determine root causes of manufacturing defects and take corrective action to prevent their recurrence, as well as six sigma processes (i.e., a statistical methodology to reduce product defects to a failure rate of 3.4 parts per million). Another common initiative is to foster consistent quality through process and product standardization.

Technology. Machine tools and their support affect factory location decisions. Besides contributing directly to production, they free limited workforces for other activities and reduce physical risk to workers. Making and maintaining machine tools are typically outside a manufacturer's core competency. The United States imports about 56 percent of its machine tools, as does Europe.[v] The United States ranks third, behind Japan and Germany, in the production of machine tools, but just ahead of Italy and Switzerland.[vi] Machine capacities often seem to exceed labor capacity, but not necessarily by a large margin. One producer characterized that margin as only 10–15 percent. As labor is typically expensive, such a margin of tooling over labor emphasizes that cost considerations do influence capacity allocations.

Manufacturers frequently fund their own R&D, often in partnership with universities or across industries. Companies consistently provide more than half of all R&D funding in the United States.[vii]

Advanced manufacturers are improving access to and distribution of designs, data, and process controls. Companies schedule across facilities, suppliers, and distributors. About 84 percent of U.S. producers have adopted computer-aided design, and 58 percent have adopted computer-aided manufacturing; only 24 percent use robotic devices to perform tasks.[viii] In addition, manufacturers are using information technology to establish virtual exchanges and markets for cost-efficient access to suppliers and markets, as well as to link research facilities in flexible, distributed virtual laboratories.

System Integration. The national environment plays a major role in determining how manufacturers balance the three factors (workforce, technology, and processes) to implement advanced manufacturing. Italy, for example, has very restrictive labor laws, leaving employers with little flexibility to reduce the workforce during lean economic times. For this reason, Italian industry favors heavy investment in technology when implementing advanced manufacturing. On the other hand, because of Hungary's more liberal labor laws and the availability of highly skilled, inexpensive labor, manufacturers in Hungary favor workforce investments when implementing advanced manufacturing.

National infrastructure affects factory location. Access to rail, highway, and sealift remains essential to the movement of supplies and products between enterprise partners and their markets. Transportation reliability and access are also important because they affect the shipping lot sizes and production safety stocks necessary to prevent line slowdown/shutdown. For one manufacturer, volume shipping rates determined the type and amount of value that it added to subassemblies. The goal was to maximize the benefit derived from the volume-based shipping costs.

MAJOR CHALLENGES

Several major challenges are associated with the advancement of manufacturing:

- Advanced manufacturing benefits from partnerships, and sustaining useful partnerships will require continuing attention to issues such as environmental responsibility, intellectual property rights as design and development activities disperse through the international value chain, and appropriate procedures for technology transfer.

- The constraint of finite resources requires selective advancement decisions. Thus, manufacturing systems need more effective production planning and control of costs. Although the ERP system provides an integrated control planning capability, there is still room for improvement because of the system's implementation difficulties.

- Pressures in workforce management include constraints on wage levels and workers' mobility. Furthermore, workforce education has been a challenge. Advanced manufacturing depends on mathematics and science basics, on decision-making skill as a key to flexibility and change management, and on the interpersonal skills necessary to ensure the rapid formation of effective manufacturing alliances and high-performance teams.

- The national strategic challenge is to keep the diffusion of manufacturing advancements economically competitive without compromising national security. Technical and infrastructure diffusion maintains value chain integrity, enables flexible enterprise partnering, and helps counteract the diminishing numbers of manufacturing suppliers. Global subtier supplier dependencies can impede unilateral surge production for defense mobilization, however. The United States might still surge quickly with coalition concurrence and capabilities, but coalition consensus building often takes time. Also, an unpopular, unilateral U.S. mobilization could suffer from a lack of global manufacturing support.

- Sustaining advanced manufacturing requires manufacturers to differentiate products as price differentiation erodes and to reduce production cycle time.[ix] One initiative can affect another. For example, quality through standardization must be balanced with flexibility and agility.

- Inadequate basic R&D slows innovation. For example, as one laboratory manager described it, the potential of robotics has been evident for decades, but engineers are still working to develop manufacturing robots "about as smart as a pretty good dog."

- Information technology will help meet some of these challenges, but it will raise issues of data and process security. It will also involve recurring costs for continual updating.

OUTLOOK

Generally, the outlook is positive for advanced manufacturing in the United States. Profitability is up, and productivity is increasing; however, the future of advanced manufacturing depends to some extent on steady growth in markets and consumption. There is some chance that international economic coalition decisions may impede foreign market access and enterprise partnerships. Several manufacturers have recognized these issues and have been working to avert the potential fracture of productive partnerships.

Constraints on manufacturing's mobilization surge capabilities are likely to continue, first because of workforce limitations. Many of the international facilities visited already employ their local workforce fully, essentially preventing meaningful surge, whether at the prime or subtier contractor level. As populations continue to age and other economic sectors grow, labor competition is likely to remain intense in industrialized nations, including the United States. Second, tooling capacity is an issue, largely as a result of the use of economic efficiency to scale factories. Economic scaling of manufacturing facilities is not likely to change without incentives. Third, although the United States leads in advanced manufacturing investment, the nation depends on imported machine tools. This foreign supplier dependency is likely to continue as globalization proceeds.

Manufacturing flexibility and dual-use acquisition strategies might meet some of the potential surge requirements. In case of an urgent need, however, such a mobilization strategy could leave commercial markets short of product and product support, thus creating sustained economic stress.

In the very long term, advanced manufacturing should evolve from distributed, large-scale production to

local, mass customization production. The establishment of a flexible, local manufacturing capability will enhance surge and distribution responsiveness.

Tooling advances also move a manufacturer up a technical pyramid; the higher up the pyramid that a manufacturer moves, the smaller the workforce that the manufacturer requires for a given amount of productivity. Efficiency and flexibility advancements are essential to sustain productivity growth with limited or declining workforces.

Advanced machines promise to do more, and more varied, operations. Multi-axis and multi-operation tools will simplify or complicate process planning and control, however, depending on the extent of system integration and the application. For example, hexapod machine tools, multi-axis positioning systems that enable 6 degrees of freedom, and other high-speed cutting tools are very precise and expand production capacity, but their operation is still based on the removal of material from stock. Nanotechnology and micro-electromechanical devices will help make the leap to growing components at molecular levels and precision, rather than machining them down to desired dimensions and current tolerances. Reducing the scale of work will improve product quality and function. The technology leap promises to improve machine durability and cost efficiency.

Manufacturers have long used polymers and powder metallurgy technology for prototypes, but virtual prototyping is on the rise. A virtual machine tool at Sandia National Laboratories, linked to a hexapod, has produced zero waste virtual prototyping—and flawless first articles. Such initiatives will improve cost efficiencies and reduce environmental impacts as manufacturers develop products rapidly and produce them in small, customized lots.[x]

As tools advance, machine–human interface and process control advancements will become more important.[xi] Information technology in the form of artificial intelligence can help to capture and develop knowledge.[xii] There will still be investment trade-offs of tool and process controls against workforce dependence and flexibility, however.

Truly flexible manufacturing should solve the long-lead components inventory buildup for product changeovers. The right information technology should help; a closer look at batch process control systems might benefit this *mass customization* production need.

Information technology will enhance partnerships through its connectivity and speed. Electronic markets and exchanges will grow to become clearinghouses for data, information, and supplies. Virtual markets and exchanges are an emerging answer to the diminishing numbers of manufacturing suppliers and should help maintain connectivity in developing economic alliances.

GOVERNMENT GOALS AND ROLE

Although manufacturers are acting to meet many of their challenges, several goals and roles remain for governments, particularly in the national and international context. The U.S. government can encourage strategic partnering by reducing barriers to capital, market, and technical information. It will be necessary to balance the benefits of fair and open market access against the risks of collusion by strategic partners, however. The transfer or licensing of technology and the transfer of equipment should remain viable in the fast-paced world of technical obsolescence. The recent presidential technical transfer policy letter is a start, but more work remains to be done, especially at the legislative level and particularly with the nation's larger trading and production partners.

Governments should further the principles of environmental responsibility. With manufacturing's aid, they should develop environmental controls and regulations. This approach may be particularly productive if pursued early, during the design stage of new tools and processes.

Several roles of the federal government have an impact on workforce availability and skills. The government could sequence and shape changes to education, health care, immigration, and retirement programs to adjust workforce supply to the demands of manufacturing efficiency. Some short-term and long-term government actions could include the following:

- Increase the number of employment-based, non-immigrant H-1B visas for college-educated professionals to fill critical workforce vacancies.

- Design a tax credit to encourage more manufacturers to invest in worker training, up to 4 percent of payroll.

- Provide incentives to state governments and educational facilities to expand vocational training, enhancing workforce skills.

The U.S. government is relinquishing its surge response capability through privatization in today's increasingly global economy. Manufacturing reallocation through flexibility offers short-term surge response, but a prolonged conflict may induce domestic economic stress (e.g., rationing and price controls). "Buy U.S." machine tool incentives could help to meet the public defense trust, arguably a greater need than meeting the public financial efficiency trust. In addition, the government may need to pay surge capacity or inventory premiums in order to maintain a surge capability in the face of competitive pressures, especially in dual-use markets. This is particularly critical as the Department of Defense develops its own just-in-time inventory and support practices and incurs foreign subtier dependencies.

Expanding markets need infrastructure. The federal government should promote international infrastructure interoperability meaningful to local needs, the international production community, and projected power supplies. Local governments can further promote manufacturing flexibility through regional industrial cluster planning, as a few U.S. cities are doing now.

To promote exports and help mitigate the effects of diminishing numbers of manufacturing suppliers, the federal government should nurture small businesses. These businesses need protection of their intellectual property rights to ensure that they have a chance to establish themselves. The government must balance manufacturers' efforts to manage knowledge against those intellectual property rights, however. Balance is also important with value chain operations, as overly restrictive protections could unintentionally discourage and hamper the effectiveness of strategic partnering.

The federal government should incentivize capital and process investments in dual-use manufacturing. The available allocation diversity would facilitate short-term surge, but reallocation could result in rationing and price controls. Meaningful, continuous, strategic, industrial mobilization planning is warranted.

The U.S. government should expand tax incentives for and invest in more basic R&D. Incentives for voluntary domestic sharing of broad technical advancements would also be appropriate. The R&D focus should be on artificial intelligence, where the competitive advantage for the nation is high, but the ROI for individual companies is low (because of the large investment required). Artificial intelligence will facilitate design, manufacturing development, and process control; relieve workforce dependency, as well as education and training costs; facilitate knowledge management; and promote modeling and simulation.

Finally, the government should promote the security of information technology through the reasonably unencumbered use of encryption and data protection architectures and practices. Protection is needed from cyberterrorism; more law enforcement funding should be targeted to this effort.

CONCLUSION

The U.S. manufacturing sector is meeting the nation's national security requirements. It is a major contributor to U.S. economic prosperity and provides superior defense products for the nation's military.

Manufacturers in the United States are excelling in a dynamic, global, and interdependent environment by transporting their products to the marketplace better, faster, and cheaper. They are achieving competitive advantage through keen insight into the complex characteristics of the changing marketplace and through the application of enabling activities that achieve an advanced level of manufacturing. The key enabling

factors identified in this study fall into four categories: workforce, processes, technology, and system integration. Major initiatives being implemented in the United States include the creative use of international and domestic partnerships, the application of ERP, and preparation of the workforce for the 21st century.

Manufacturing sector weaknesses include a shortage of skilled workers, a limited surge capability to meet security requirements, and vulnerabilities to infrastructure attack. Businesses will continue to respond to these challenges by focusing their efforts and resources on establishing and maintaining core competencies. The federal government must contribute by taking steps to strengthen the workforce, expand investment in basic R&D, ensure a surge capability in areas critical to national security, and improve Internet security.

ESSAYS ON MAJOR ISSUES

CREATIVE PARTNERING IN ADVANCED MANUFACTURING

Scott Coale and Bill Schofield

As markets have become more global, competition has increased, and manufacturers have found it necessary to adapt to remain competitive. One approach manufacturers are pursuing to retain their competitive advantage is engaging in creative partnerships.

Public–Private Partnerships

Partnering with National Laboratories. The semiconductor industry has joined with the national laboratories in the Extreme Ultraviolet Lithography (EUVL) Project. The objective of this arrangement is to develop the next generation of lithography technology, the process used to print integrated circuits on silicon wafers. A limited liability corporation formed by the four major U.S. chip manufacturers (i.e., Intel, Motorola, Advanced Micro Devices, and Micron) funds the project. Three national laboratories (i.e., Lawrence Livermore, Sandia, and Lawrence Berkley) have teamed in a Virtual National Laboratory (VNL) to accomplish the work. In developing the EUVL technology, the VNL also works in close cooperation with U.S. lithography tool manufacturers.[xiii]

Although the four participating chip manufacturers are direct competitors, they have decided to cooperate and share the risk and cost of developing the next generation of lithography. This arrangement benefits the national laboratories, because they are able to preserve their in-house expertise despite deep cuts in government spending. The laboratories' role will ensure that U.S. chip manufacturers have first access to EUVL tools, giving them a competitive advantage over foreign competitors. The VNL estimates that this project will accelerate the availability of EUVL tools to U.S. manufacturers by about 3 years.[xiv]

Partnering with Universities. In another example of public–private partnering, manufacturers have teamed with universities to develop advanced manufacturing technologies and processes. While this has really been the continuation of a longstanding relationship between industry and educational institutions, the focus of industry-sponsored research has changed during recent years. Industry used to invest both in long-term basic research and in applied research, but recent industry sponsorship has focused on the applied research that will offer a near-term ROI.

Universities are actively engaged in transferring technology developed with public funds to U.S. industry. The universities visited have established technology transfer offices to exploit the Bayh-Dole Act of 1980,[xv] licensing university developments for the financial benefit of the university and the commercial benefit of the licensing company. A 1998 survey indicated that this technology transfer adds $33.5 billion to the U.S. economy and supports 280,000 jobs per year.[xvi]

While partnering with universities was once an arrangement unique to the United States, this phenomenon is now taking hold in Europe. For example, Agusta, an Italian helicopter manufacturer, is increasingly looking to universities to supplement its internal engineering capability.

Private–Private Partnerships

Contract Manufacturing. With the current economic boom, worldwide demand for advanced manufacturing products has grown. Manufacturers have responded by contracting for additional capacity to supplement their production capability. Globalization of the marketplace has facilitated this growth in contract manufacturing. As more of the world has opened its markets, technology has spread to new areas, and manufacturers have gained access to skilled labor in these areas.

Hungary, for example, offers companies both access to Europe and highly skilled labor at very competitive prices. At the facilities visited, the average electronics assembly line worker earned about $400 per month, and the average factory engineer earned about $1,400 per month. Videoton, a privately owned Hungarian electronics manufacturer, had tripled its business during the last 5 years to more than $200 million in 1999, as it provided contract manufacturing for companies such as IBM, Sony, Siemens, and Philips.[xvii]

Supply Chain Management Consolidation. Some manufacturers are pooling their purchasing power to achieve economies of scale with suppliers. Ford, General Motors, and DaimlerChrysler shocked the automotive industry this year when the traditional rivals announced plans to integrate their supply chain management efforts. The companies will establish an independent company empowered to purchase parts for all three automobile makers. This venture will enjoy the same e-commerce advantages available to individual companies, but with the added advantage of unprecedented economies of scale; projected business will exceed $240 billion.[xviii] Not to be outdone, the world's four largest defense contractors announced a similar plan in March. Boeing, Lockheed Martin, Raytheon, and BAE Systems will pool their buying power in a venture scheduled to begin operation this summer.[xix]

Strategic Partnering. Companies in the same industry are teaming with greater frequency. According to Coopers and Lybrand, companies engaged in strategic alliances achieve greater growth and productivity than their counterparts.[xx] By combining their core competencies with the strengths of partners, these companies achieve a competitive product. Alliances with worldwide partners offer the added advantage of opening markets that favor regional producers. The Italian manufacturer Agusta has successfully developed multiple partnerships. Since the 1950s, Agusta has teamed with Bell, Sikorsky, Boeing, McDonnell-Douglas, and Westland of the United Kingdom. Through these foreign partner arrangements, Agusta has produced more than 4,500 helicopters for customers in 80 countries, most resulting from licensed production or co-development projects.[xxi]

ENTERPRISE RESOURCE PLANNING

Scott Coale and Janet Felts

The mention of information technology naturally brings to mind the dot-com companies that dominate today's business news. Traditional "brick and mortar" manufacturing companies are also using information

technology to improve productivity and achieve competitive advantage, however. One of the more powerful information technology implementations helping manufacturers achieve this advantage is ERP.

A software-implemented concept, ERP increases efficiency while improving customer satisfaction. By means of a suite of software functions, ERP makes information available throughout the enterprise to anyone who needs it to make an informed decision. It links the entire organization, affecting logistics, finance, human resources, inventory management, production planning, sales, order processing, and distribution. As Davenport noted, "The great benefit of ERP is integration. If you add a new sales order to the system, everything related to the order also changes, including sales commissions, inventory requirements, manufacturing schedules, and the balance sheet."[xxii]

This integrated tool makes it possible to achieve two important goals in today's demanding marketplace: inventory reduction and customization. A recent market research study indicated that a $1 billion company with average growth and inventory turnover can save $40–$150 million through effective inventory control.[xxiii] Because ERP provides total inventory visibility, manufacturers have the confidence to adopt a just-in-time delivery system from suppliers and, thus, to reduce inventory. Enterprise resource planning also helps companies respond to growing consumer demand for customized products. As globalization increases competition, consumers are becoming less tolerant of mass-produced, one-size-fits-all products. With ERP, companies have a flexible tool that allows them to respond to customized requests without incurring tremendous costs. Once a salesperson enters a customized order, ERP software identifies the required parts, schedules manufacturing, creates a bill, and schedules shipping.

ERP's Current Status

Although ERP's potential is clear, the recent track record for implementation is mixed. During the 1990s, 56 percent of the manufacturing sector implemented some form of ERP with varying results.[xxiv] The Meta Group surveyed 60 of these companies and identified two reasons for the mixed results: high cost and lengthy implementation. The average total cost amounted to $15 million, and the average implementation time for a comprehensive ERP system was 23 months. Most companies required more than 5 years to achieve a positive return on their ERP investment.[xxv] One of the most publicized ERP blunders occurred at Hershey Foods in 1999. Hershey missed the planned implementation date for its $112 million ERP package, fouling up the company's candy shipments for both Halloween and Christmas. The resulting shipping delays, inability to fill orders, and excessive warehouse inventory resulted in a 12 percent reduction in third quarter sales and a 19 percent drop in quarterly profits.[xxvi],[xxvii]

A recent RAND study indicates why companies struggle with information technology–related transformations.[xxviii] RAND's analysis shows that, although information technology offers the potential for companies "to become more productive, more intelligent, and more adaptable," these benefits become a reality only for those companies "prepared to change in form and philosophy." In the case of ERP, companies must overhaul their business practices; they cannot continue business as usual if they intend to exploit the potential benefits. Oswald Mata of Deloitte Consulting summed up the business process challenge best: "Having ERP alone is not going to give you a competitive advantage. It's what you do with it…that makes you competitive."[xxix]

Weak leadership can also impede the implementation of ERP. Implementation Management Associates, a software consulting agency, found in a survey of companies experiencing difficulty with ERP implementation that 90 percent identified turf issues as a major barrier. Managers fear that the wide availability of information will undermine their authority and their positions, so they "slow roll" implementation.[xxx] To combat this resistance to change, upper management must communicate a vision linking the company's future success to ERP implementation. Without a persuasive campaign and commitment to personnel training from senior leadership, politics and personal jealousies can derail even the best ERP system.

Outlook for ERP

While some companies are struggling with the basic implementation of ERP, others are looking ahead toward additional benefits from their investment. For example, business-to-business e-commerce via the Internet can benefit greatly from ERP. The secret to success in this endeavor is a new definition of the "enterprise" in ERP. Most ERP success stories have focused on integrating all business operations within one company, even across multiple geographical locations. The next step is to expand the definition of the "enterprise" and integrate the supplier chain and the customer into the network.

Expanding the enterprise begins with a focus on supply chain management. A company can optimize supply chain management by linking its ERP system with suppliers.[xxxi] The electronic link lets companies exploit e-commerce by locating the best price and delivery date among competing suppliers. Texas Instruments is one of the few companies already using a global, supply chain management–capable ERP system. Texas Instruments has integrated 56 of its plants and suppliers' plants worldwide to order, manufacture, and deliver more than 45,000 devices. The system has already reduced production cycle time and lowered costs.[xxxii]

Companies are also linking their systems with those of their customers to help increase the customers' efficiency.[xxxiii] To increase a customer's confidence that a supplier can support the customer's just-in-time delivery requirements, the supplier can provide an "available-to-promise" inventory. The customer can access the company's database to determine whether the company can meet its schedule requirements. Although another company might offer a similar product at the same price, this customer relationship management gives the company a competitive advantage

The trend toward integration with suppliers and customers has not been lost on ERP software companies. *Informationweek* reported that the five largest ERP vendors are adapting their ERP packages to facilitate supply chain management and customer relationship management. Although these vendors saw a slowdown in demand for ERP systems in 1999, the advantages offered by e-commerce are generating demand for ERP packages with these capabilities.[xxxiv] As experience is showing a rapid ROI of 300 percent, these software vendors expect continued growth in e-commerce modifications to ERP software.[xxxv]

Recommended Government Policies

First, and most important, the government must lead a joint government–industry effort to ensure the security of the Internet against cyberattacks. The Clinton Administration established a defense against cyberterrorism with Presidential Decision Directive (PDD) 63, but it is necessary to expand this initiative. Current efforts focus on defending the infrastructure against attacks and rely on voluntary industry participation. As the manufacturing sector becomes more reliant on e-commerce and the Internet, the U.S. manufacturing base becomes more vulnerable to cyberattack consequences. A coordinated attack could paralyze the entire manufacturing sector. The government must extend participation in PDD-63 initiatives to the manufacturing community and provide greater incentives (e.g., tax credits, technology-sharing arrangements) for participation.

A second initiative that the government should pursue is to increase investment in information technology R&D. At the present time, the government sponsors a great deal of manufacturing R&D through the National Science Foundation, the National Institute of Standards and Technology, and programs such as Small Business Innovative Research and the Manufacturing Technology Program. Much of this investment focuses on projects that benefit narrow sectors of the manufacturing industry. As an alternative, the government could invest R&D funds in technologies such as information technology that benefit the manufacturing community at large and enhance the competitive advantage of more U.S. firms. Most manufacturing companies are relying more and more on information technology and would benefit from breakthroughs in this area. One example would be investing in technologies that make information technology systems and telecommunications more affordable. The biggest drawback to a company's adoption of ERP and e-commerce is often the huge initial investment.

21ST CENTURY WORKFORCE DEMANDS

Rebecca Halstead and Al Vogel

Manufacturing is dependent on the human resources supporting it. Once confined to making a product from raw materials, manufacturing now includes knowledge and ideas as raw materials. Consequently, a company's capital now encompasses intangible assets such as organizational knowledge, ability to innovate, and value-added services.[xxxvi] The demands of advanced manufacturing require educated, highly skilled, well-trained, and empowered employees. Hans Morgenthau said it best: "The quality and productive capacity of the industrial plant, the know-how of the working man, the skill of the engineer, the inventive genius of the scientist, the managerial organization—all these are factors upon which the industrial capacity of a nation and hence its power depend."[xxxvii]

Current Status of Human Resources

According to the National Association of State Workforce Investment Policy Council, the most challenging issue facing the United States is the issue of human resources. Cost cutting and downsizing have triggered a crisis in traditional workforce development programs. The nation's capacity to prepare a skilled workforce for the future requires a significant investment of private sector resources.[xxxviii] In fact, a coordinated response of government, education, and private industry is necessary to address the way that today's emphasis on quality, flexibility, and cost-effectiveness affects workforce education and training.[xxxix]

A recent Grant Thornton survey of manufacturers cited the main reasons for productivity gains as improved worker training (16 percent) and the combination of better people and technology (16 percent).[xl] This is a major shift from the early 1990s when technology received most of the credit for any increased productivity. Manufacturers now realize that most state-of-the-art equipment is no more efficient or effective than the person who operates it. However, finding qualified, skilled workers remains a major problem, according to 63 percent of those surveyed. An aging workforce, especially in welding and machining, has been a significant contributor to the problem.[xli]

The competition for talent is taking place both within the managerial ranks and on the manufacturing plant floors. A 1998 survey of students who were working toward a master's degree in business administration at top U.S. business schools produced unsettling results. Only 4 percent identified engineering and manufacturing as the field they most wanted to work in upon graduation, and within this number, 57 percent did not expect to stay with their first employer longer than 5 years.[xlii] Furthermore, data introduced to the Small Business Committee hearing in the U.S. House of Representatives in February 2000 indicated a shortage of 240,000 skilled plant workers in the United States today. In addition, the age of the workforce is rising rapidly in many skilled occupations. Because there is a long developmental period for educating and training a highly skilled workforce, there is no quick resolution to these issues.[xliii]

Outlook for Human Resources

Investing in people is the key to competitive advantage in the 21st century. As MIT economist Lestor Thurow wrote, "Brainpower will create new technologies, but skilled labor will be the arms and legs that allow one to employ the new product and process technologies that are being generated. Skilled people...become the only...sustainable competitive advantage."[xliv] Manufacturing market leaders who have re-engineered their human resource functions and empowered their workforce with training programs are increasing productivity, improving quality, and inspiring innovation.[xlv] Several common themes and trends have become evident regarding education and training for employees in the manufacturing industry:

- The pace of technological change continues to transform the manufacturing workplace, requiring multiskilled "knowledge workers" able to deal flexibly with information-based, computer-integrated technologies and to participate in decisions related to process and product improvements.

- In flatter, high-performance manufacturing environments, workers must also have the communications and business knowledge to work in teams and accept responsibility for customer satisfaction.

- The retirements of many skilled workers and the lack of both basic and specialized technical/craft skills in new hires exacerbate the challenge of maintaining a skilled workforce.

- The pool of workers interested in careers in manufacturing is shrinking because of the lack of updated information and the poor image of the industry.[xlvi]

Recommendations

The solution for meeting the nation's demand for a skilled workforce is multifaceted and requires partnerships between government, businesses, and schools. The government should aggressively implement the policies already approved in legislation. In 1994, for example, Congress enacted three pieces of workforce development legislation: (1) the School-to-Work (STW) Opportunities Act, to help young people become competent, career-directed, credentialed students;[xlvii] (2) Goals 2000—Educate America Act, to establish national academic standards for subjects such as science, mathematics, and economics;[xlviii] and (3) the National Skills Standards Act, to provide a framework for program evaluation instruments and tools for individual performance assessments.[xlix],[l]

It is important to support and pass House Bill H.R. 1824, a bill providing targeted tax credits for skilled apprenticeships. Because it takes years of apprenticeship to produce highly skilled workers, the United States cannot wait for an economic crisis to initiate an appropriate program. H.R. 1824 targets the problem with tax relief of $15,000 per year, per employee to train new apprentices. This federal policy will provide the economic stimulus to attract and train skilled workers in the manufacturing sector.

Industry must take the lead and join with educational institutions, families, and communities to expand and focus training opportunities. Expertise from industry is necessary to create learning environments that foster the development of schools and curricula needed for a 21st century, highly skilled workforce. Industry leadership is essential to link industry needs and education policy.[li]

[i] *Merriam-Webster's Collegiate Dictionary*, 10th ed., *s.v.* "manufacturing."

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[iii] U.S. Embassy, Budapest, *The Hungarian Economy*, 23, February 2000, 2, http://www.usis.hu/econ.htm.

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[v] National Association of Manufacturers, *Growth, Technology and Innovation: The National*

Association of Manufacturer's High-Tech Agenda (January 2000).

[vi] The Association for Manufacturing Technology, *1999–2000 Economic Handbook of the Machine Tool Industry*, AMT Statistical Department (1999), F-5.

[vii] National Association of Manufacturers, *The Facts about Modern Manufacturing*.

[viii] National Association of Manufacturers, *The Facts about Modern Manufacturing*.

[ix] . David Viale, *Basics of Manufacturing: Fundamental Concepts for Decision Makers* (Menlo Park, CA: Crisp Publications, Inc., 1995), 3–7. This text presents "industry's top four needs" as (1) delivering high-quality products, (2) reducing costs, (3) bringing products to market faster, and (4) making change faster and more manageable.

[x] This challenge parallels Grand Challenge 4 found in National Research Council, *Visionary Manufacturing Challenges for 2020*, Committee on Visionary Manufacturing Challenges, Board on Manufacturing and Engineering Design, Commission on Engineering and Technical Systems (Washington, DC: National Academy Press, 1996), 27. Grand Challenge 4 reads: "Reduce production waste and product environmental impact to 'near zero.'"

[xi] This challenge parallels Grand Challenge 2 found in National Research Council, *Visionary Manufacturing Challenges for 2020*, 17. Grand Challenge 2 reads: "Integrate human and technical resources to enhance workforce performance and satisfaction."

[xii] This challenge parallels Grand Challenge 3 found in National Research Council, *Visionary Manufacturing Challenges for 2020*, 24. Grand Challenge 3 reads: "Instantaneously transform information from a vast array of diverse sources into useful knowledge and effective decisions."

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[xxiv] E. Knorr, “ERP’s Rough Waters,” *Upside* (December 1999): 209.

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