

CHAPTER 9

# The Future Of Manufacturing

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*Technology Trends*

This chapter is a story about the future of manufacturing based on three predictions:

- that firms of all sizes will have increasing access to high-performance computing capabilities that will enable sophisticated modeling and simulation of both new products and production processes;
- that additive manufacturing will become commercially competitive across a wide range of industries and will support the use of multiple materials; and
- that new business models relying on information technology (IT) will reduce the administrative overload both of bidding and winning contracts and of delivering products and services.

If these predictions play out, it will favor localization of manufacturing over today's more centralized, economies-of-scale production models based most recently on offshore outsourcing. A fourth trend — a rise in the number of hobbyists who become designers and producers of one-off and small-lot products — will change the definition of "manufacturer" and may, in fact, return manufacturing to the garage. An IT-driven transformation in the manufacturing sector is inevitable.

## INTRODUCTION

Technology has been revolutionizing industrial sectors for more than 200 years. We have seen the way mechanized production increased productivity during the Industrial Revolution when it replaced workers performing repetitive tasks. We have also experienced the way IT and computing have revolutionized the means by which production is planned, managed, accounted for, inventoried and even delivered. But the divide between the computing haves and have-nots has grown in the past decade, and nowhere has this been a more serious problem than in the manufacturing sector. A recent series of workshops conducted by the National Academy of Engineering highlights why this divide is so important, suggesting that adding value, and thus capturing a higher percentage of that value, means integrating innovation, design, manufacturing and service delivery. This will require a systems-wide view of the innovation-to-production process, and it may favor entrepreneurs. Kate Whitefoot and Steve Olson, authors of a report on the workshops' findings, believe that "there is no better time [than now] to be a talented entrepreneur who can take innovations and scale them rapidly, digitally and globally."

In essence, this chapter presents a story based on predictions about the changes in store for the industrial supply chain, including changes in the relationship between larger original equipment manufacturers (OEMs) and their suppliers. This is also a story about the changing dynamics within current supply chains, where the traditional David-and-Goliath relationships are evolving. If these predictions are borne out, David may triumph over Goliath more frequently in the future, and at least will enjoy the luxury of increased self-determination.

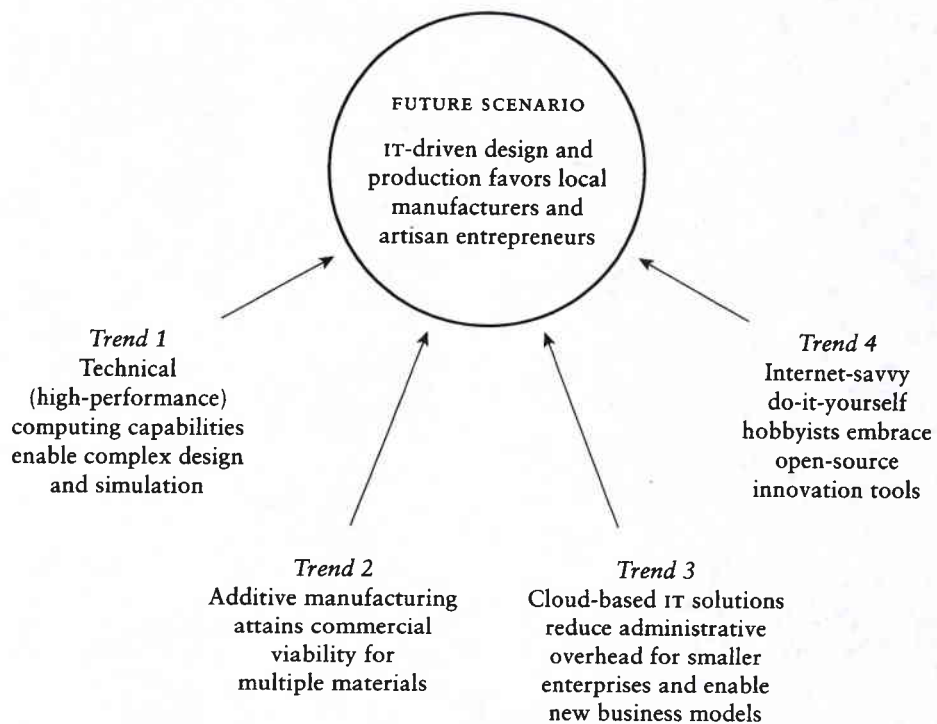
## THE POTENTIAL FOR A REVOLUTION IN THE MANUFACTURING SECTOR

Strategic roadmapping<sup>2</sup> has been used successfully to help companies develop scenarios of the future, and the recent growth of *outside-in* thinking<sup>3</sup> emphasizes the importance of sensing and sense-making in the external environment for determining the critical forces that will be game changers. At the heart of this approach lies a need to capture the breezes

of today that will turn into the gales of change for tomorrow. But it is rare that a single trend by itself is a disruptive force. Instead, it is the combination of multiple, often seemingly unrelated trends that presents truly disruptive future scenarios.

There are four trends that have the power to revolutionize the manufacturing sector. These four trends suggest that the current arrangement of tiered supply networks based on low-cost production and economies of scale is unlikely to dominate in the future. Instead, IT-driven design and production will favor local manufacturers and artisan-entrepreneurs (Figure 1).

**FIGURE 1: *Four Trends With the Potential to Revolutionize the Manufacturing Industry***





## **HIGH-PERFORMANCE COMPUTING CAPABILITIES TAKE SOPHISTICATED MODELING MAINSTREAM**

The first trend is related to the increasing availability of high-performance computing capabilities beyond traditional research labs and large manufacturers. Many tools developed over the past two decades that support product-development innovation are well understood in the manufacturing environment, and their combination with automation technologies has transformed the factory floor. CAD/CAM, combined with the capabilities of computer-numerical controlled (CNC) machines, has boosted productivity and is commonplace in most manufacturing firms, regardless of size or sector.

Less well understood by the majority of companies are the tools that support testing, advanced analytics and simulation. Large companies such as Boeing have been designing, simulating and testing digitally for over two decades. The CATIA product-design software developed by Dassault Systemes enabled Boeing engineers and designers to see parts of engines as solid images and then simulate the assembly of those parts on the screen, easily correcting misalignments and other fit or interference problems. But while the use of modeling and analytics has increased, it is still a relatively rare capability for the typical small or medium-sized enterprise (SME). A study of 232 manufacturers conducted in 2010 by the National Center for Manufacturing Sciences and Intersect360 Research found that 61 percent of companies with over 10,000 employees are using high-performance computing to model their designs digitally, yet only 8 percent of companies with under 100 employees are using this technology.<sup>1</sup> This same study found that the most significant barriers to adoption of high-performance modeling and simulation technologies were lack of internal expertise, the cost of software and, to a lesser extent, the cost of hardware.

To introduce SMEs to the potential of digital modeling and analytics, the National Digital Engineering and Manufacturing Consortium (NDEMC) was created in 2011 by the U.S. Department of Commerce's Economic Development Administration. NDEMC is a regional initiative focused on Midwestern manufacturers and includes partners such as John Deere, Lockheed Martin, General Electric and Proctor & Gamble.

There are currently 20 different ongoing projects in its portfolio that span alternative energy, medical devices, cooling systems and plastics.<sup>5</sup>

The consortium is already helping SMEs. Jeco Plastics is a small custom-mold manufacturer of large, complex and high-tolerance products for large OEMs in the automotive, aerospace, printing and defense industries. The company uses rotational molding and twin-sheet pressure-forming processes and employs materials ranging from commodity thermoplastic resins to highly complex resins with continuous unidirectional carbon fibers.

Recently, Jeco received a last-minute design change for a custom pallet that it was designing for a large German manufacturer. Jeco was able to access high-performance computing resources through NDEMC. Using the center's "ABAQUS" modeling and simulation tool developed by Dassault Systems, Jeco was able to analyze the needed design changes, resulting in a multi-year contract with estimated annual orders of \$2.5 million. Under normal circumstances, these high-performance computing resources would have been beyond Jeco's reach due to budget constraints and a lack of modeling and simulation expertise.

Such successes should spawn similar efforts in other regions of the United States. Critical to these efforts will be access to hardware and software, combined with the expertise needed to develop and interpret the analytics and simulations they produce. To date, most manufacturing sectors, and particularly the SMEs within them, have failed to invest in these capabilities.

### **ADDITIVE MANUFACTURING COMES OF AGE**

The second trend that will significantly influence the future of manufacturing is the increasing commercial viability of additive manufacturing, which is also known as "3D printing."<sup>6</sup> This process, involving the layer-by-layer creation of objects, has been used for rapid parts prototyping and small-run production in a variety of industries for more than two decades. But recent developments in its capabilities — the introduction of new machines and their declining costs — have begun to move additive manufacturing into more mainstream part production. Interestingly, low-capability and low-cost machines have begun to engage the interests of designers far beyond traditional manufacturers, a point to be addressed later in this chapter.

Rick Karlgaard, publisher of *Forbes* magazine, has speculated in his "Innovation Rules" column that "3D printing may be the transformative technology of the 2015-2025 timeframe." Similarly, Terry Wohlers, a leading expert in the additive-manufacturing industry, believes that additive-manufacturing technology "could very well have a greater breadth of impact on manufacturing than any other technology in recent history."<sup>8</sup>

While additive manufacturing is, in fact, a digitally based trend in manufacturing that frequently relies on high-performance computing for sophisticated modeling, it deserves to be singled out as a key disruptor in its own right. Additive manufacturing uses computer-generated designs to create "build paths" that reproduce the digital model through consolidation of materials with an energy source. The process typically uses a laser or an electron beam that adds material as it is directed along the build path or can be scanned over a pre-placed layer of material. To date, additive manufacturing has been used with polymers, metals and ceramics.

The principal value of additive manufacturing lies in its potential to lower costs through reduced material usage and machining. Furthermore, the technology enables the design and creation of features that are extremely difficult to construct through traditional processes. From a customization and volume standpoint, additive manufacturing offers extreme flexibility for product differentiation, making it feasible to create highly complex one-off components and products.

In the realm of traditional manufacturing, additive manufacturing has long been used in rapid prototyping to create short-term molds or to develop mock-ups of parts, generally in some type of plastic form. These prototypes were considered precursors to the "real" parts design, which would be produced to tighter tolerances and in the actual final material, which was seldom plastic. But additive manufacturing has continued to move closer to that final production run in industry sectors such as healthcare, where dental and prosthetic devices are being produced with this process for final use, and has been migrating into higher-tolerance and complex materials industries, such as automotive and aerospace.

For example, in November 2012 GE Aviation bought Morris Technologies, a small, privately owned precision-engineering firm. Its specialty? Additive manufacturing. Morris will be developing parts for a range of jet engines,

including the LEAP, which is being developed by DFM International. This engine is expected to enter service in commercial airlines in the coming years, and 4,000 units already have been ordered.<sup>9</sup> Morris begins with a digital description of the component and uses laser sintering to build it layer by layer. This process is capable of producing all types of metal parts, including those made of aerospace-grade titanium.

Currently, fused-deposition modeling is the most common additive-manufacturing technology available at the consumer level. This process, one of computer-controlled deposition of melted plastic, is found in recently introduced products for consumers and businesses like the Makerbot, RepRap and Solidoodle. Already, 3D printing has become cost competitive: MakerBot recently introduced a \$2,199 3D printer, and costs continue to fall. Jeff Kowalski, CEO of Autodesk, a leading software maker for 3D modeling and printing, notes that the cost of 3D printers has dropped tenfold in five years, "essentially riding the Moore's Law curve, just as 2D printing started doing in the 1980s."<sup>10</sup>

Wohlers has reported that it took the additive-manufacturing industry 20 years to reach \$1 billion in size. Sales of additive-manufacturing products and services are predicted to reach \$3.7 billion worldwide by 2015 and to surpass \$6.6 billion in 2019.<sup>11</sup>

### **CLOUD-BASED SOLUTIONS REDUCE COSTS, LEVEL THE PLAYING FIELD FOR SMES AND ENABLE NEW BUSINESS MODELS**

The third trend that may disrupt current manufacturing-supply-chain practices is the increasing use of cloud-based solutions that can be accessed on an as-needed basis. Cloud computing is likely to enable SMEs to more effectively compete with larger companies because it reduces the cost of accessing sophisticated design, development and enterprise-related business tools. If this trend continues, SMEs will not be hobbled by the prohibitive cost of purchasing and maintaining comprehensive IT systems. The cloud effectively enables both internal decision making and new business models.

From a business-process innovation perspective, information technology improves internal decision making through software that provides support for enterprise resource planning (ERP), material requirements



planning (MRP) and supply-chain-management logistics. These types of IT solutions help manufacturers develop a deeper understanding of the needs of their businesses, the flow of their work and the integration of the supplier network into a cohesive solution. While these solutions have typically been used successfully by large companies, SMEs will increasingly be able to take advantage of these enhancements.

In the future, many large-scale, legacy ERP systems will transition to cloud-based solutions. But these new solutions will require a different approach to IT management within the manufacturing environment by using a software-as-a-service (SaaS) deployment model for ERP implementations.

### **HIAWATHA RUBBER GOES CLOUD-BASED FOR ERP**

Based in Minneapolis, Hiawatha Rubber is a family-owned designer and manufacturer of custom-molded rubber parts and assemblies for OEMs. Hiawatha recently replaced an aging, in-house ERP system with a cloud-based ERP solution from Plex Systems, an independent software vendor specializing in cloud-based manufacturing software. While their old system could provide basic information, it lacked the ability to provide the detailed, real-time and accurate financial and manufacturing information that company decision makers needed. This was particularly challenging when they were trying to integrate production data with costing and quality data.

Following a three-month implementation — about half the time it took to install the original in-house system — Hiawatha managers were able to see the value of real-time visibility. According to Tim Carlson, a company manufacturing manager, “the plant-floor employees now see upcoming jobs and where materials are located in real time, enabling them to make quicker and better decisions. Now when a customer calls for a rush order, we can tell them in minutes when their order will be ready, compared with several hours and a significant amount of manual effort when we had our previous system in place.”<sup>12</sup>

The company’s website proudly advertises this capability, saying: “Our extensive and sophisticated enterprise resource planning system lives in

the cloud, giving us a platform that's typically only found at Fortune 500 companies."<sup>13</sup>

Just as the cloud has created new business models in retail, entertainment and journalism, it is doing so in manufacturing, with improved internal visibility, customer-relationship management and the extension of product sales into services. The cloud-based business model allows manufacturing franchises to compete locally and on a smaller scale using Internet-based tools. Drexel Metals is a good example of this emerging model, going beyond the Hiawatha Rubber example to focus on internal company business-process innovation.

#### **DREXEL METALS ESTABLISHES A DISTRIBUTED MANUFACTURING NETWORK SUPPORTED BY WIKIS AND INTERNET TOOLS**

In 1985, Drexel Metals was a steel supplier making everything from lighting fixtures to ceiling ribs for the construction industry. But its customers began asking for metal roofing products, where 80 percent of the market is dominated by traditional go-to-market factories selling pre-fabricated roof panels ready for installation. According to company President Brian Partyka, "a challenge with pre-fabricated metal roofing is that when you ship it, you're shipping unwieldy sections that require a lot of packaging to protect them during transport."<sup>14</sup>

Instead, Drexel Metals decided that the best way to get its product to both residential and commercial customers was through a network of specialty installers who could fabricate the "standing-seam" metal roofs onsite. This eliminated expensive shipping and also reduced the lead time necessary for contractors and installers. Now Drexel Metals sells one- to two-ton coiled metal rolls in 36 colors, and it offers installers the ability to buy or lease-to-buy a portable roll-forming machine that can transform these rolls into the specific standing-seam roof desired by the customer. But the company didn't stop there. As a way to support remote fabrication, Drexel developed cloud-based tools and services that enhance their customers' ability to plan for, bid and win sophisticated roofing jobs. In short, through a network of regional manufacturers, Drexel Metals now orchestrates a supply chain that runs from the steel