The Promise of Smart Manufacturing

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The competitiveness of a nation's manufacturing sector requires a common pool of capabilities – such as skilled labor, robust supply chains, and specialized services—that together constitute what has been labeled the "Industrial Commons".[1] The more robust the Industrial Commons, the stronger the manufacturing base. And when the Industrial Commons is eroded or weakened, it can be difficult or impractical to restore.

Today, the Industrial Commons is changing. The capabilities needed to ensure competitive success today are different from what they were at the turn of the century. And these capabilities are likely to differ in another five years. The reason? Technology and globalization are transforming where and how goods are produced. To be a successful manufacturer in today's hyper-competitive global marketplace requires relentless innovation to achieve ever-higher levels of productivity.

Nowhere is this more apparent than in *smart manufacturing*—defined as "the integration of sensors, controls, and software platforms to optimize performance at the production unit, plant, and supply chain levels."[2] Such integration, facilitated by the Industrial Internet of Things (IIoT), allows for real-time decision making via data analytics, including the use of artificial intelligence (AI) techniques, such as machine learning. According to consulting firm Deloitte, "the smart factory represents a leap forward from more traditional automation to a fully connected and flexible system—one that can use a constant stream of data from connected operations and production systems to learn and adapt to new demands."[3] This leap forward has been described as a new industrial revolution—one based on digitalization of the supply chain—and a worthy successor to the previous revolutions based on steam, mass production, and information technology. In 2013, Germany branded their efforts to guide this "fourth industrial revolution": Industrie 4.0.

The promise of smart manufacturing is based on a wide array of emerging applications. For example, the application of AI in industrial settings has enabled predictive maintenance (e.g., networked sensors can pick up subtle changes in equipment that may indicate impending failure), enhanced quality control (e.g., an aircraft engine manufacturer can inspect turbofan blades in 3-D with micrometer precision), demand-driven production, inventory optimization, reduced energy and material costs, product design (e.g., Airbus has used generative techniques to create aircraft parts that are significantly lighter than those designed by humans), improved safety, and environmental performance.

[1] See Gary Pisano and Willy Shih, 2012. *Producing Prosperity*, Harvard University Press: Cambridge, MA.
[2] This definition comes from the following source: National Science and Technology Council, 2018. *Strategy for American Leadership in Advanced Manufacturing*, Office of Science and Technology Policy, October.
[3] Deloitte, 2018. *The Smart Factory: Responsive, Adaptive, Connected Manufacturing*. Deloitte University Press.

These applications are just the tip of the iceberg. When value chains are fully linked digitally to smart factories, unique new applications are likely to emerge; the possibilities are seemingly limited only by entrepreneurial imagination.

The breadth and magnitude of the potential economic impact from smart manufacturing is substantial, and manufacturers of all stripes are taking notice, as recent surveys and marketing forecasts indicate:

- In a qualitative study, Deloitte identifies five characteristics of a smart factory: connected, optimized, transparent, proactive, and agile. Benefits can be expected across a range of categories, including asset efficiency, higher quality products, lower cost, and enhanced safety and sustainability.[4]
- According to a 2018 Accenture study involving interviews across the globe, manufacturing executives believe the pressure to innovate has never been higher, and 71% think AI will have a transformative impact by 2020.[5]
- A July 2017 survey of US-based manufacturers conducted by MAPI and PwC found that 38% of manufacturers are now offering IIoT-driven products and services; an additional 48% are currently in the process of developing them.[6]
- According to a 2015 McKinsey Global Institute analysis of more than 150 use cases, the Industrial Internet of Things (IIoT) can be expected to create between $1.2-3.5 trillion in value added in 2025.[7]
- A 2017 Capgemini survey of 1000 executives of large manufacturing companies (>$1B in annual revenue) led to estimates of the economic impact from smart manufacturing ranging between $1.2 billion and $3.7 trillion in global value add by 2025, and between $500 billion to $1.5 trillion by 2022. This represents a 7x increase in overall productivity by 2022. For a typical automotive original equipment manufacturer (OEM), this productivity increase represents a doubling of operating profit.[8]
- A 2016 US Department of Commerce survey of 80 US manufacturers and vendors suggests that smart manufacturing would provide $57 billion dollars in annual cost reductions.[9] This represents an approximate 3.2% reduction in the shop floor cost of production. Enhanced sensing and monitoring, seamless transmission of digital information, and advances in analyzing data—each has the potential to save manufacturers in excess of $10 billion annually.

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[4] Deloitte. 2017. *The Smart Factory: Responsive, Adaptive, Connected Manufacturing*. Deloitte University Press, London.

[5] Accenture. 2018. *Manufacturing the Future: Artificial Intelligence will fuel the next wave of growth for industrial equipment companies*.

[6] PricewaterhouseCoopers (PwC) and the Manufacturers Alliance for Productivity and Innovation (MAPI). 2017. *Monetizing the Industrial Internet of Things*. PwC. July.

[7] McKinsey Global Institute. 2015. *Unlocking the Potential of the Internet of Things*, McKinsey & Company, June.

[8] Capgemini Digital Transformation Institute. 2017. *Smart Factories: How can manufacturers realize the potential of the digital revolution*? Capgemini Consulting.

[9] Anderson, Gary, 2016. Department of Commerce. "The Economic Impact of Technology Infrastructure for Smart Manufacturing," NIST Economic Analysis Briefs 4, October.

- A variety of market research firms estimate the global market for smart manufacturing over the next 5-10 years to be in the hundreds of billions of dollars range: "To reach USD $395.2 billion by 2025" (Grand View Research), "$339B by 2028" (Future Market Insights), "$479B by 2023" (Statista), "$205B by 2022" (MarketsandMarkets), and "$595B by 2023" (Orbis Research).

Despite the substantial benefits that smart manufacturing may bring, such results won't be easy to achieve. Smart manufacturing faces stiff headwinds.

First, robust processes and devices will not spring up overnight; the needed technologies—such as industrial applications of AI—are evolving. Furthermore, the expertise needed to develop, operate, maintain, and utilize these technologies takes time to cultivate and at sufficient scale to meet demand.

Second, investment cycles in the manufacturing sector are extremely long; complete capital replacement does not happen overnight. The emergence of true "smart factories" will likely begin with new, "greenfield" production facilities; existing factories will adopt smart technologies much more slowly—probably over decades.

Third, the smart manufacturing revolution depends critically on *information governance*: rules (formal and informal) concerning the collection, flow, and analysis of information, often in digital form. These rules are determined over time through collective action by governmental and nongovernmental organizations. Get the rules right, and the promise of smart manufacturing will (eventually) become a reality. Get the rules wrong, and smart manufacturing will never fully materialize. Information governance matters.

To explore information governance issues in some depth, the Manufacturing Policy Initiative at Indiana University hosted an October 19th roundtable event in Washington, DC featuring executives from nearly twenty manufacturers, each having a global presence. We invited policy experts in academia to contribute papers on specific topics—AI in manufacturing, technical standards, cybersecurity and privacy, and digital trade policy—to inform and help spur the facilitated discussion. Our purpose is to spark a conversation among policy makers and manufacturers about fulfilling the promise of smart manufacturing in the United States.

For the full promise of smart manufacturing to be realized, a step-change increase in both quality and efficiency must be obtained through the real-time analysis of massive amounts of information from within a factory and across the supply chain. This will be achieved through the application of AI. In the paper entitled, "AI and Manufacturing," David Crandall defines AI, traces its history, describes its strengths and weaknesses, and provides examples of its successful application in a manufacturing setting. A key point is that the factory floor represents a promising venue for AI because it is a controlled environment with limited variables.

For the IIoT to flourish, devices up and down the supply chain must be capable of communicating with each other. Interoperability is a must for smart manufacturing, and this requires a common language—standard protocols for communication. Only through the development of global standards can smart manufacturing reach its full potential. In the paper entitled, “Technical Standards,” Angus Low provides an overview of the standards-development process: the major players, the sheer magnitude of activity underway, and the role that national governments are taking by positioning their country as a first mover. A paradox emerges—technology often moves faster than standard setting, yet standard setting is needed to promote technological development. Firms that seek a competitive edge today have to weigh the pros of being an early adopter with the cons of investing in technologies based on standards that may soon become obsolete. This is a value-of-information problem—the longer a firm waits for a stronger signal of emerging standards, the more certain it can be of a positive investment return, but the less likely the firm will lead the new industrial revolution.

Perhaps the most glaring obstacle to the promise of smart manufacturing is the risk of a cyberattack. In the paper entitled “Smart Factories, Dumb Policy?”, Scott Shackelford describes a world where a security threat emerges and is then addressed, only to result in a continuous cycle of ever-more insidious attacks that require real-time development of effective countermeasures. Given the severity of the problem, prevention becomes an imperative. Shackelford describes policy proposals and private-sector actions that together create a polycentric governance to protect the cyber “commons.” The reader is left with the impression that such polycentric governance is not only inevitable but also necessary for smart manufacturing to flourish. With respect to privacy, Shackelford emphasizes the leadership of the EU with its General Data Protection Regulation (GDPR)—applicable to manufacturers and driving other countries to develop their own policies. Regulatory requirements to ensure privacy will continue to evolve over the next few years.

Smart factories link digital technologies with production processes. The technologies underpinning smart factories (e.g., 3-D printing, IIoT, etc.) will transform trade in manufactured goods. As Susan Aaronson points out in her paper, “Digital Trade Policy,” this transformation is pushing policymakers to update trade policies and agreements and develop interoperable norms governing data. However, only two trade agreements, CPTPP and NAFTA 2.0—neither of which is yet in effect—include provisions governing cross-border data flows. Nations are not approaching these issues uniformly. Whereas the US policy is to support a free flow of information across borders, the EU is regulating (restricting the use of) certain types of personal data, and other countries (e.g., China) are restricting the flow of information (e.g., through data localization requirements). Trade disputes have and will continue to arise and be decided before digital trade policy evolves enough to give manufacturers greater certainty.

Manufacturers cannot wait for perfect policy to emerge—the journey to smart manufacturing has already begun, and competitiveness considerations demand participation. In the final paper, “Challenges and Opportunities,” Keith Belton describes the perception of 18 manufacturing executives as they react to these issues from a business perspective. The reader comes away with a sense of urgency and frustration—urgency to lead in smart manufacturing for competitiveness reasons and frustration over a lack of certainty over these information governance issues. Other related issues also emerge—such as the difficulty in acquiring expertise in data analytics and AI—a problem compounded by the current skills gap in US manufacturing.

As one reads through these issue papers, certain themes emerge:

1. Information governance will impact how and when companies invest in smart manufacturing. Technology alone will not create smart factories—the right policies must also be in place to enable these technologies and reduce unnecessary barriers to market entry.

2. Collective action is needed to create governance conducive to investment. Much of this collective action is being initiated by manufacturers themselves, working in coordination with service providers. For example, the increasing availability of cybersecurity insurance is driving best practices throughout supply chains to reduce vulnerabilities. But in some policy areas of import, only governmental action will provide the certainty that drives investment. With respect to digital trade policy, for example, rules on cross-border data flows will eventually emerge through new trade agreements and the resolution of digital trade disputes.

3. The US strategy/approach to these information governance issues is not as clear as those of other leading manufacturing nations. China's top-down approach (known as "Made in China 2025," and backed by a significant level of resources) and Germany's coordinated approach (where government, industry, and academia are in lock-step to achieve Industrie 4.0) stand in stark contrast to the USA's market-driven approach (which admittedly has its own advantages). And although the US is making some effort to advance innovation policies to encourage the development of new technologies (e.g., the Manufacturing USA institutes), information governance is receiving much less attention. In fact, there is a noticeable lack of coordination among the various federal departments and agencies engaged in these information governance issues.

4. Policy makers must consider the unique features of domestic manufacturers when crafting policy to address issues of information governance. These features include the distinction between information technology (IT) and operations technology (OT) (which has implications for cybersecurity), the complexity of 21st century supply chains (e.g., the need for information flow within and across global value chains), and the capabilities of smaller firms (e.g., to participate in standard setting development and adoption). Public policy must be informed by such considerations or it is unlikely to attain its objectives.

Smart Factories: Issues of Information Governance is based on a premise: smart manufacturing requires the right set of policies in order to flourish. The competitiveness of domestic manufacturing is at stake.

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