The Manufacturers' Dilemma:

The Benefits, Risks, Policies/Laws, Ethics, and Global Reach of Smart Manufacturing

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I. Introduction

Dubbed the next Industrial Revolution, Smart Manufacturing (SM), a fully integrated, collaborative manufacturing system designed to meet changing demands and conditions in smart factories, is on the brink of revolutionizing the way in which manufacturing and business are conducted. Providing businesses with more insight, control, and transparency across supply chains, increasing employment opportunities, the ability to predict and resolve potential problems, and allowing experts to troubleshoot from anywhere in the world through Digital Twins, a digital representation of a physical object, process, or service, are just some of the many benefits associated with SM. Yet, despite these advantages manufacturers seem hesitant to jump in to create such factories. When evaluating the benefits of SM, manufacturers must also assess its risks and challenges, including the costs of this investment.

Smart Manufacturing (a/k/a Industry 4.0 or fourth industrial revolution) is defined by the National Institute of Standards and Technology (NIST) as the "fully-integrated, collaborative manufacturing system that responds in real-time to meet changing demands and conditions in smart factories" (McKewen, 2015). Similar to the finance industry, the manufacturing industry is ready to harness the value of technological advancements and invest in Artificial Intelligence (AI). The results of a recent survey conducted by Small-Medium-Sized Enterprises (SME) support the interest in using AI by manufacturers. According to the SME survey, the top three goals motivating companies to invest in SM technologies are to increase the speed of manufacturing production (75%), ensure product/service quality (61 %), and provide more value to customers (45%) ("Smart manufacturing: 7 essential building blocks," n.d.; *See Table 1*). Further, SM features such as "enhanced sensing and monitoring, seamless transmission of digital information, and advances in analyzing data and trends have the potential to save manufacturers in excess of $10 billion annually" (Anderson, 2016). Yet, despite these promising gains, many manufacturers are still reluctant to implement SM. As revealed by this study, while 49 percent, almost half of the respondents believe the manufacturing industry will see significant changes over the next 12 months, less than one-third of respondents 30 percent are in the process of implementing or using SM solutions, and 26 percent have not yet researched this technology ("Smart manufacturing: 7 essential building blocks," n.d.; *See Table 2*).

In an effort to address the issue of SM cost barriers, in particular for SMEs, the U.S. government proposed the Smart Manufacturing Leadership Act offering grant funding to states to assist with investment in the new technologies and also for training employees in the use of such technologies (*S.715 - 116th congress (2019-2020); "*Smart Manufacturing," n.d.). Challenging ethical concerns also confront manufacturers, since shifting to SM will change the role and perception of labor. Pursuant to a 2017 National Council on Compensation Insurance study, since 1990 U.S. automation in manufacturing has not only reduced production costs but has simultaneously reduced the requirement for labor (Bourne, 2020). In contrast, an Industrial and Financial Systems-Artificial Intelligence study (IFS-AI study) reveals that "the investment in technology has the potential to upskill existing employees and increase employment in business functions or industries that are not in direct competition with AI" (*Ibid*). This paper will examine how cost impediments along with legal and ethical concerns regarding data privacy and security, loss of certain jobs and the creation of others, and existing laws such as the Smart Manufacturing Leadership Act, help shape and influence manufacturers' decision-making about investing in SM.

II. Smart Manufacturing Defined and Explained

The Smart Manufacturing Leadership Coalition (SMLC) defines SM as the "ability to solve existing and future problems via an open infrastructure that allows solutions to be implemented at the speed of business while creating advantaged value" (McKewen, 2015). SM, Smart Industry, or Industrial Internet are synonyms for Industry 4.0 or industrial transformation in the fourth industrial revolution of the U.S. Similarly, this transformation in manufacturing has and is occurring in other parts of the world as demonstrated by Germany's Industry 4.0, Japan's Society 5.0, and China's Made in China 2025 (*See Table 3*).

During the First Industrial Revolution, advancements in production occurred due to the use of water and steam-powered engines. In the Second Industrial Revolution steel and electrical energy were used. With the Third Industrial Revolution, there was a change to digital/Information Technology and automation software. SM allows for the elements of smart technology, such as sensing inputs, computing power, always-on connectivity, artificial intelligence, and advanced data analytics, to replace the traditional production process with one based on cyber-physical production systems ("What is Industry 4.0?*,"* n.d.). The cyber-physical production systems refer to a "manufacturing environment that offers real-time data collection, analysis, and transparency across every aspect of a manufacturing operation," in the environment knowns as smart factories (*Ibid*). A research study conducted by Maja Barring (Barring) for her Doctor of Philosophy describes how the manufacturing industry is poised and ready for a digital transformation that many experts and scholars predict will be the next or Fourth Industrial Revolution. Barring further explains the modern production system, a Cyber-Physical-System, and the process of data transforming into fact-based information essential for manufacturer's decision-making (Barring, 2021; *See Figure 1*).

SM has the potential to revolutionize manufacturing strategy by changing expensive traditional factories into profitable innovation centers through linking industrial automation, Industrial Internet of Things (IIoT), and Information Technology (IT) including cloud services, 3D models, mobile computing, intelligence, and integration platforms ("Cost-effective solution for end-to-end manufacturing," n.d.; Leiva, 2015). Many of these IIoT are equipped with sensing elements to relay information or communicate back to centralized hubs. For example, tracking devices on trucks, environmental monitors in factories, or cameras on the assembly line comprise what is known as IIoT designed to monitor steps of the supply chain and factory conditions (*Ibid*). Industry experts acknowledge these cutting-edge changes in the manufacturing sector when noting that "software is driving the advances in today's manufacturing, meaning that the mouse is replacing the wrench in many places on today's factory floor" (Jacinto, 2014).

Recognizing SM as the use of data and technology to assist people and machines, organizations like Manufacturing Enterprise Systems Association (MESA), the Industrial Internet Consortium (IIC), and the SMLC have brought together manufacturers, technologies, and information systems to lay the groundwork for SM initiatives ("The Industrial Internet Consortium and the Manufacturing Enterprise Solutions Association Sign Mou," n.d.; "On the journey to a smart manufacturing revolution," n.d.). These industry insiders realize that through SM, the manufacturing industry will be able to solve supply and production issues based on a total picture, occurring in real-time.

III. The Benefits of SM

SM provides manufacturers with greater insight, control, and data visibility across supply chains. SM has the potential to improve productivity, increase energy efficiency, reduce waste in the manufacturing process, increase higher quality products, and sustain a safer work environment for companies (Anderson, 2016). SM is capable of bringing products and services to market faster, more inexpensively, and with better quality allowing companies to gain a market advantage (*Ibid*). SM's connected and efficient systems also allow companies to maintain a competitive advantage. Not surprisingly, the IFS-AI study which surveyed over 600 industry leaders using Enterprise Resource Planning (ERP), Enterprise Asset Management (EAM), and Field Service Management (FSM), found that 90 percent of manufacturers are looking to invest in AI (Bourne, 2020). AI together with other technological advancements such as 5G and the IoT yield not only profits but also the ability for manufacturers to continue to create new production systems and processes (*Ibid*). Communication that occurs in real-time between a company's enterprise systems and automated equipment in smart factories allows AI to effectively respond to a company's most challenging business models, such as custom manufacturing or engineer-to-order type manufacturing (*Ibid*).

Additionally, SM will increase employment opportunities in smart factories. The IFS-AI study indicated a future work environment for manufacturing in which both AI and humans work together. According to the study, respondents viewed AI as a route to create, rather than remove, jobs with 45 percent of survey respondents indicating that they expect AI to increase hiring, while 24 percent believe it will not impact their workforce figures (Bourne, 2020). Experts also foresee new direct manufacturing and non-manufacturing positions arising out of new technology-based manufacturing jobs created by SM (Leiva, 2015). However, employees, in particular IT personnel, need to learn the "manufacturing systems, protocols for equipment integration, and how manufacturing data flows into business intelligence and corporate metrics," so that manufacturers have the opportunity to exercise more in-depth decision making ("On the journey to a smart manufacturing revolution," n.d.). SM, for example, has the ability to predict when potential problems or issues are going to arise before they actually happen (Anderson, 2016). SM's predictive analytics, real-time data, internet-connected machinery, and automation, therefore, allow manufacturers to be proactive rather than reactive when dealing with supply chain management issues that may arise (McKewen, 2015). For manufacturers will have trusted data upon which to rely when making decisions.

IV. The Challenges of SM

While SM yields many advantages for the manufacturing industry, manufacturers will need to invest in both the physical infrastructure and human labor required to operate, maintain, and update smart factories. Key challenges for manufacturers revealed in the SME study are finding skilled people (34%), knowing where and how to begin (26%), changing existing process (17%), developing a strategic roadmap (14%), and return on investment (13%) ("Smart manufacturing: 7 essential building blocks," n.d.; *See Table 4*). Costs impediments to SM include those associated with new technologies and employee training to operate and maintain smart factories (Anderson, 2016). Employees/workers will need to learn how to configure and maintain smart machines and robots. Employee buy-in and the ability to adapt and change so the technologies make work easier and not harder must be part of the corporate culture for successful SM implementation (Leiva, 2015; "Industry Today," n.d.). Thus, manufacturers need to provide training for their employees to acquire the skills to work in smart factories and/or must invest time seeking employees with the requisite technological skills needed for working in smart factories.

Another main challenge to SM implementation includes the risks of data and security breaches due to the connected network systems integral to smart factories. Relying on cloud-based technology, manufacturers are concerned that their data will be vulnerable to "external attacks and data misuse," such as cyber-attacks and hacking from both within and without the organization

(Phuyal, 2020). Securing proprietary information, intellectual property is another related concern ("Attacks on Smart Manufacturing Systems - Trend Micro," n.d.). Manufacturers do not want their new discoveries, inventions, or secret recipes, like the formula for Coke, to become known in the public domain or to be revealed prior to a company's own announcement or launch of a new product or service.

V. Policies, Laws, and Ethical Considerations Surrounding SM

A report on the Smart Manufacturing Leadership Act (SMLA) was issued to the senate in 2019 outlining the level of involvement of the U.S. government and its interest in the expansion of U.S. Smart Manufacturing (S.715 - Smart Manufacturing Leadership Act). The SMLA addresses the development of SM technologies such as advanced technologies in information, automation, monitoring, computation, sensing, modeling, and networking (*Ibid*). On October 29, 2021, this bill was re-introduced to Congress in an effort to revive the bill to become law (*Smart manufacturing leadership act of 2021 - congress.gov*). Pursuant to the SMLA, the Department of Energy (DOE) has been tasked with completing a national plan for SM technology development to improve the productivity and energy efficiency of the U.S. manufacturing sector. Under Congressional directive, the DOE may issue grants to states to support their efforts in SM. In particular, the DOE will provide funding for investment in smart manufacturing technologies and to be used for training employees on the tools necessary to provide technical assistance in smart manufacturing technologies and practices" (*S.715 - 116th congress (2019-2020))*.

Manufacturers must be forward thinkers in employing the new technologies and production systems for manufacturing. Yet, they must also be mindful of both positive and negative intentional and unintentional consequences which may result when implementing SM. Manufacturers need to consider existing laws in the areas of AI and decision making and AI and

Patents and draw from the knowledge of all manufacturing stakeholders, employees, lawyers, and data scientists to assess a company's risks. There are also potential liability risks with the use of AI. For example, whether an algorithm aligns with the values and true outcomes of the organization itself, and the impact this may have on employees, vendors, customers, and society in general. It is also possible for there to be manipulation of the algorithm or data provided to AI that would impact decisions in ways that are unethical and/or were not contemplated by the organization (Bourne, 2020). Similar to liability risks with self-driving cars, manufacturers must understand that liability and responsibility are assigned not on the basis of the algorithm or the data inputs to AI, but with the underlying motivations and decisions of humans (Bourne, 2020). Further, Article I, Section 8 of the U.S. Constitution, defines who can be a patent owner, however, this law was created with humans not AI in mind leading to much uncertainty and debate about whether AI can be an owner of its own invention under U.S. patent laws (Kelion, 2019).

A reliance on technology, according to Professor Margot Kaminski of the University of Colorado Law School, often leads to 'Automation Bias,' in which decisions made by machines are trusted more than those made by humans (Bourne, 2020). Prof. Kaminski explains, "a lawyer may be interested in different kinds of explanation compared to a computer scientist, for example, an explanation that provides insights into whether a decision is justified, whether it is legal, or allows a person to challenge that decision in some way" (Bourne, 2020). AI and Machine Learning Systems by definition lack transparency. Since "data is fuel for AI," manufacturers must ensure that this data complies "with the privacy, data security and other laws that apply to the data" ("Legal Perspectives for Technology & Innovation," 2019). Additionally, algorithms are viewed by businesses as proprietary, which leaves everyone but the creators of the AI, "unable to determine why an algorithm produced a specific output, recommendation, or assessment," making it difficult to determine instances of bias or discrimination in AI decision-making (Stahl, 2021). This leads to the importance of why the ability of all SM stakeholders, attorneys, data scientists, and managers, to discuss and analyze how AI decisions are made is essential for manufacturers, organizations, as well as society.

Another ethical and legal challenge for manufacturers to consider is the privacy and security of customers' data. Under various state and federal laws, companies are required to develop, implement, and maintain reasonable safeguards to protect the security, confidentiality, and integrity of consumer private information. Section 5 of the Federal Trade Commission Act, provides that the FTC has "enforcement power over unfair and deceptive commercial acts and practice," which courts have interpreted to include data privacy practices. Flexing its enforcement powers under Section 5, the FTC has entered into settlement agreements with companies regarding their data privacy and security practices (*Federal Trade Commission act - federal reserve board*).

In addition to the tools on the factory floor changing, wrench replaced by mouse, the faces on the factory floor will as well. One of the many ethical issues manufacturers and society, in general, will encounter is the replacement of human workers in some areas of production and other forms of work. AI, Machine Learning, and robots work autonomously and can do so seven days a week for 24 hours a day. No sick days, no lunch or restroom breaks, no light nor window needed (Walsh, 2019). However, humans are and will remain the most important asset for a manufacturer as they will be freed from mundane and repetitive tasks to perform higher-level thinking. Change is never easy, but as the previous industrial revolutions have shown, it does occur and throughout history, humans have been able to adapt and reshape their purpose and value in terms of how they work (*Ibid*).

VI. Global/Domestic Markets and Digital Twins

The Information Technology and Innovation Foundation (ITIF) issued a report explaining how SM effects modern manufacturing and production processes. While the report details the benefits of smart manufacturing, it also reviews the current policies that prominent world nations are implementing to achieve leadership in SM. Overseas manufacturing facilities in German, China, and Japan have been and are being constructed using SM technologies (Jacinto, 2014; Industry Today; *See Table 3*). Additionally, this report provides policy recommendations for the U.S. to consider and implement in support of the U.S manufacturing industry, so this industry may leverage the full potential of SM (*"*A policymaker's Guide to Smart Manufacturing," n.d). Thus, to remain competitive in global markets, the U.S. will need manufacturers who are willing to invest in and create similar rival smart factories which enable SMEs to access different forms of business intelligence through the use of AI (McKewen, 2015).

Similarly, to remain competitive domestically, SMEs will require technological systems and processes in place to provide the same or better services to customers and clients than those of larger companies like Amazon. One such example is the use of Digital Twins, essentially a digital replica of a physical object or system. As a mirror image of an object or system, Digital Twins are not only powerful tools for innovation but allow experts to troubleshoot technology issues in SM facilities from anywhere in the world ("Where can CSPS use Digital Twins," n.d.). For the cyber-physical production systems of SM, Digital Twins make it possible to assist with operations, processes, customer experience, and partner ecosystems (*Ibid*).

VII. Conclusion

Smart Manufacturing is touted to be the next or Fourth Industrial Revolution. At its core, SM is the integration of product development through production and servicing with the goal to optimize value and profitability for manufacturers. SM promises among other things, efficiency, predictive analytics, reduced costs/waste, and access to troubleshooting capability from anywhere in the world through Digital Twins. Yet, its true value for manufacturers lies in its ability to grow and change with the shifting needs of an organization. Despite some hesitation by U.S. manufacturers in its adoption, due to labor and technology costs and the legal and ethical uncertainties, the many benefits realized by Smart Manufacturing, more significantly, the opportunities it affords Small-and-Medium-Sized Enterprises to continue to manufacture increasingly high value, high-profit margin parts and products in the U.S., and to remain globally competitive, will eventually lead to manufacturers' acceptance of Smart Manufacturing.

VIII. Further Research Suggestions

Issues to explore requiring further and future research should focus on laws and policies that manufacturers will need as they consider investing in SM and which are yet uncertain or currently being developed. Also lacking are skilled workers ready to be employed in smart factories. This is supported by statistical data from the U..S. Department of Education which reveals that "60 percent of the new jobs that will emerge in the 21st century will require skills possessed by only 20 percent of the current workforce" (Jacinto, 2014). The ability to upskill or reskill present and future employees is an area in which educators and educational institutions could effectively respond, like with the introduction of STEM programs, and begin to play a more active role in preparing students so they possess the necessary skills and knowledge for future jobs or careers in Smart Manufacturing.

Some advice for SMEs and manufacturers still hesitant about investing in SM, consider taking incremental steps when investing in new technologies; using private-public partnership business models to defray costs, and relying on cloud-based SM to access data instead of the more costly physical infrastructures associated with SM. It is also advisable to offer products and services by leveraging IoT to assist with more outcome-based solutions which will expand business opportunities.

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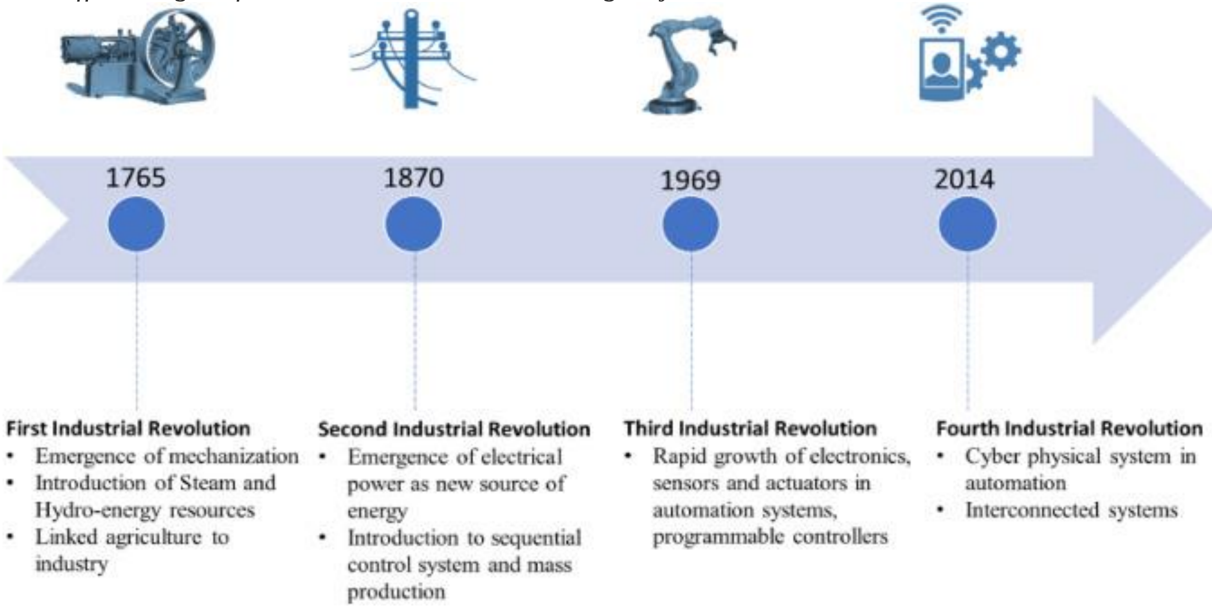
Figure 1

The different ages of the industrial revolution noting major achievements/inventions.



Source:

Phuyal, S., Bista, D., & Bista, R. (2020, May 1). *Challenges, opportunities and future directions of Smart Manufacturing: A state of art review*. Sustainable Futures. Retrieved October 1, 2021, from https://www.sciencedirect.com/science/article/pii/S2666188820300162

Table 1

Goals motivating companies to invest in new manufacturing technologies

Goals	Percentage
To improve speed of manufacturing production	75
To ensure product/service quality	61
To provide more value to customers	45

Note. The top three reported goals of firms/companies choosing to invest in smart technologies according to a survey conducted by SME.

Table 2

Manufacturers' views about smart manufacturing

Goals	Percentage
Foresee significant changes to manufacturing within the next year	49
Are in the process of implementing smart manufacturing solutions	30
Have not started investigating the technology	26

Note. Viewpoints expressed by manufacturers regarding smart manufacturing according to a survey conducted by Small Medium Sized Enterprises (SME)

Table 3

The characteristics of newly introduced smart technologies

Strategy Declared	Industry 4.0	Made in China 2025	Society 5.0	Industrial Internet
Originating Country	Germany	China	Japan	USA
Focus area	SME Worldwide	Industries of China	Smart Society primarily in Japan and rest of the world	Industries worldwide
Major Contribution to the field	Digitization of manufacturing industries worldwide	Making China as leading country in manufacturing in the world	Digitization of society in 12 major fields	Digitization of Industries through internet
Year Introduced	2011	2015	2016	2012
Base Technology	Internet and Interconnected devices	Internet and Interconnected devices	Internet and Interconnected devices	Internet and Interconnected devices

Note. A comparison of the strategies, target audience/group, contributions to the field and year initiated among four major countries in their approach to implementing smart technologies.

Source:

Phuyal, S., Bista, D., & Bista, R. (2020, May 1). *Challenges, opportunities and future directions of Smart Manufacturing: A state of art review*. Sustainable Futures. Retrieved October 1, 2021, from https://www.sciencedirect.com/science/article/pii/S2666188820300162

Table 4

Challenges to implementing smart manufacturing technologies

Challenges	Percentage
Finding skilled people	34
Figuring out where to begin	26
Changing existing practices	17
Developing a strategic roadmap	14
Return on Investment	13

Note. Some key challenges facing manufacturers when implementing smart manufacturing technologies according to a survey conducted by SME.