**Implementation of Industry 4.0 Smart Manufacturing**

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Abstract

The industry 4.0 will bring profound changes to our society, including an important digital shift in the manufacturing sector. At present, several manufacturing firms are trying to adopt the practices of industry 4.0 throughout their supply chain. This paper aims to examine how manufacturing firms or companies can employ Industry 4.0 smart manufacturing to ensure faster production with more precision and lesser human manipulation. The paper also examines several technologies and enabling factors which make the manufacturing system “smart.” These technologies are Additive manufacturing, Information technology-based production management, Cloud manufacturing, etc., and enabling factors are regulations and laws and training and innovative education. Additionally, the paper examined step by step approach to implement Industry 4.0 smart manufacturing. The main steps include identifying business objectives; developing prototype, validation of prototype, replication of prototype and total roll-out. There can be several challenges during the implementation such as the requirement of new skills, effective data security and investment needs. The challenges can be addressed by continuous training of workers; making significant investments of turnover in the acquisition of new digital technologies and improving efficiency by connecting sensor data and operations across several lines and machines.

1. Introduction

Smart manufacturing is a recent concept in the arena of manufacturing. As per this concept, manufacturing systems are completely integrated and collaborated in a way as to respond in real time to fulfil changing conditions and demands in the supply network, in the factory, and in customer requirements. Several manufacturing firms are trying to adopt the practices of industry 4.0 during their entire supply chain. Smart manufacturing is about enhancing our manufacturing processes to do more with less, fast and better! And the industrial analytics and Industrial Internet of Things will play main part in facilitating it. According to Lee et al. (2014), this improvement in productivity and efficiency allows the customization of items designed with a view to mass production.

Thus, all manufacturing companies, whether already modernized or in the process of modernization, are potential customers for companies wishing to improve manufacturing production processes. These belong to nine sub-sectors that are interrelated. Indeed, according to Brettel et al., the success of Industry 4.0 rests on the coordination of these different sub-sectors such as robotics and automation; advanced simulation software; horizontal and vertical integration systems; cyber security; the Internet of Things; cloud (cloud); 3D printing (additive manufacturing); big data analysis and augmented reality (Brettel et al., 2014). Therefore, both a robotics company and a cyber-security solution company can participate in the modernization of a manufacturing company in the context of Industry 4.0. Similarly, since these nine sub-sectors are complementary, companies wishing to modernize must invest in each of them.

This paper aims to examine how manufacturing firms or companies can employ Industry 4.0 smart manufacturing to ensure faster production with more precision and lesser human manipulation. The paper will also justify the implementation of smart manufacturing by means of examples from manufacturing industry leaders such as Siemens AG, General Electric, Renault, Secomea, etc. Keeping in view how the Internet is revolutionizing the world of business, these companies have also adopted Industry 4.0 smart manufacturing measures in all of their business operations and are currently the major providers of Industry 4.0 solutions in the manufacturing sector.

1. Industry 4.0 Smart Manufacturing

Conventionally, manufacturing was restricted to a sequence of procedures or a process through which raw resources are transformed into end products (Mittal et al., 2017). Though, manufacturing nowadays contemplates the data-driven business operations at various levels resulting in the development of several manufacturing paradigms, of which emerged Industry 4.0 Smart Manufacturing. Future smart manufacturing systems will have exclusive characteristics of self-assembly to create customized and complex products to exploit the existing and new markets. Smart Manufacturing employs info to constantly uphold and enhance performance (Lee et al., 2014).

Industry 4.0 is fundamentally characterized by smart automation and the incorporation of novel technologies into the enterprise value chain. It is a digital transformation that is shaking up the manufacturing business by carrying fundamental variations not only to processes and systems, but also to styles of management, workforce and the business models (Shrouf et al., 2014).

The concept of industry 4.0 has its roots in a German reflection completed in 2011. This reflection launched by the German regime, and then led by the academia of the country and by key industrial partners such as Siemens AG. The aim was to describe the parameters that could place the German manufacturing industry as the most productive in context of flexibility and productivity.

1. Technologies and Enabling Factors

Smart manufacturing does not operate in vacuum, and there are several technologies and factors which make and enable the manufacturing to be “smart.” In their seminal research, Mittal et al. (2017) developed a comprehensive list of 38 technologies and 7 enabling factors in industry 4.0 Smart manufacturing.

* 1. Technologies in Industry 4.0 Manufacturing

There are several technologies which can be implemented during manufacturing operations such as product design, process & plant design, engineering, operation and service. For example, Siemens offers open cloud platform for industry customers based on SAP HANA technology. Some of the important technologies in industry 4.0 Smart manufacturing are mentioned in the following section (Mittal et al., 2017).

**Additive manufacturing**: This is the technology that can print a 3-D picture into an article with the assistance of electron beam, laser beam, and so on; and as the articles are produced surface by surface. Additive manufacturing is frequently mentioned as being part of the state-of-the-art manufacturing realm.

**Information technology-based production management:** This includes technologies like Enterprise resource planning (ERP) and Supply chain management (SCM). ERP is the system that can coordinate and integrate various business parts, like human resources, inventory and marketing. SCM is the management of finance, material and information from one party to other.

**Cloud manufacturing:** This is the technology that uses actual demand to choose the planning of production and preparation. Big data can be regarded as a part of cloud manufacturing, but as the uses of Big data are so extensive, it cannot be considered as a part of cloud manufacturing.

**Advanced manufacturing:** This is the technology that can incorporate technology-centred systems of production like computer integrated manufacturing (CAM), reconfigurable manufacturing system (RMS), flexible manufacturing system (FMS) and additive manufacturing.

**Big data/Data analytics:** This is the technology that can examine huge sets of data counting actual information that are hard to investigate by customary approaches. Big data usually handles transforming the variety, volume, accuracy and velocity of data into insights and actions within a manufacturing system.

* 1. Enabling factors in Industry 4.0 Smart manufacturing

Like integration of technologies, smart manufacturing becomes possible by several enabling factors. For example, Siemens enables smart manufacturing via sensors, computing power, storage capacities, data analytics and networking ability. Some of the important enabling factors in industry 4.0 Smart manufacturing are mentioned in the following section (Mittal et al., 2017).

Regulations and Laws: There are several regulations and laws like labour law, intellectual property rights and environmental laws that a manufacturing organisation should follow relying on the nature of its work. These regulations should be strictly followed for consistent operations of a manufacturing organisation.

Training and innovative education: Education must assist a person to not only do their individual work but also dwell on how the service or product they are working for can be enhanced for the advantage of the end-users. This mind-set and innovation knowledge can simply be infused in the workforces with the assistance of entrepreneurial values and appropriate training. Consequently, knowledge workforces should be a part of state-of-the-art training and education.

Standards and Data sharing systems: “International Organisation for Standardization” (ISO) has described “STEP AP 242” and other “STEP” components as internationally standardised data models that can be employed to interchange information and patterns on general computer formats by several organizations. Likewise, simulation data can be shared by “core manufacturing simulation data”. Moreover, data sharing can be facilitated by enterprise integration between original equipment manufacturers and small and medium enterprises.

1. Action Areas for Implementing Industry 4.0

Crnjac et al. (2017) presented eight action areas which should be considered during the implementation of smart manufacturing.

**Process and Resources**: Improvement of process through effective usage of materials, upsurge the creation of value. An instance of enhancing the production of cement can be via computer system used for stabilizing, controlling, and optimizing the process of production.

**Effective usage of property:** This involves the enhanced usage of production machines. All machines must be maintenance protective because it is the only method to avert unintended stoppage of machineries. For instance, General Electric proposes software solutions for protective maintenance in which data is collected about the machine status by means of a range of sensors and allowing well-timed improvement with minimum expenditures.

**Operations:** In this action area, it is essential to upsurge the operations speed by generating a working atmosphere constructive to workforces. With the intention to decrease stoppages and waiting times, it is essential to decrease the tasks complexity, divide them into several jobs, and create a prototype so workers will turn out to be more acquainted with jobs. Robots can assist labours in manufacturing; they should do hard jobs. For instance, universal robots are nowadays on the market. They collaborate with workforces in manufacturing.

**Inventories:** It is essential to decrease the extreme production and procurement of materials for anonymous purchasers. For instance, Wurth Corporation proposes storage solutions. It is case that comprises camera to indicate the condition of the materials in the case.

**Quality:** The uneven procedures in manufacturing generate low-quality goods and result in bigger expenses. With the assistance of innovative process controller, it is probable to respond timely and correct the procedure, to decrease poor goods.

**Demand and Supply:** The comprehensive knowledge of client requirements can result in consumer satisfaction and top quality. Innovative examination can bring about the estimated demand by 80 per cent on a weekly-basis. For instance, the corporation Renault proposes configurator for all types of cars.

**Marketing Time:** It is essential to reach the desired market with a novel product, quicker than others, generates a benefit, upsurges incomes and permits quicker reaction to the possible issues.

**Maintenance and Service:** Proposing clients different solutions of "distant" maintenance is a great benefit. The firm Secomea proposes software solutions which can be a stable and robust connection with manufacturing machineries and state of machineries can be measured without remaining actually subsequent to them.

1. Step by step method to implement smart manufacturing Industry 4.0

The implementation of smart manufacturing Industry 4.0 should be in accordance with the phased approach. These steps should be coupled with the innovative manufacturing practices and the usage, connection and integration of new technologies to produce value-added exportable products that enable the manufacturing firm to grow dynamically in its market. These steps include identifying business objectives; developing prototype, validation of prototype, replication of prototype and total roll-out (See figure) (Frost and Sullivan, 2017).

**Step 1: Identifying Business Objectives**

Prior to applying smart manufacturing Industry 4.0 in an organization, it is essential to determine needs and challenges. Most of Industry 4.0 initiatives begin because of operational managers aiming to improve or resolve their everyday problems at the workplace. Feedbacks from managers and workforces help to determine the needs and challenges. Consequently, the first stage of the method includes recognizing and comprehending the operational problems line managers continually face in plant.

Some potential challenges confronting line managers and workforces comprise the absence of efficiency and quality in operations, higher costs (which may comprise cost of operations, power poor quality), fewer resources or their ineffective usage and failure to deliver solutions/products to customers (Wang et al., 2016).

**Step 2: Developing Prototype**

The next step includes developing a plan to execute a trial Prototype with a small budget. The Prototype should include devices and sensors in order to bring innovation in four areas: Product innovation, Process innovation, Organizational innovation and Market innovation (Kang et al., 2016).

The product innovation includes developing new products to significantly improve products or a new service, to maintain or increase market share, to expand product line, to increase competitiveness, and to give business a competitive advantage.

The process innovation includes adopting new manufacturing processes or new distribution methods, improving processes or methods already in place and purchasing new production equipment to reduce production time, decrease costs and give business a competitive advantage.

The organizational innovation includes rethinking about the organization of the workplace or its ways, changes the supply chain, restructure its activities, review knowledge management and enter into new alliances or partnerships to encourage a culture of innovation, better use of the skills of staff, improve the productivity of business and increase competitiveness.

The marketing innovation includes adopting or significantly changing the marketing practices of products, use new media or advertising techniques to market products, change product placement methods, promote the products more effectively, bring the products to new markets, extend life cycle of the products and respond more quickly and more adequately to the needs of the customers.

**Step 3: Validation of prototype**

The innovative prototype should be measured and authenticated for management's support. Data gathered by sensors from the pilot devices, can recognize factors or areas of inefficiency that might bring about greater flaws. Organizations can employ this info for improvements of process to decrease waste. These improvements of process can then be applied at the factory for an additional round of collection of data. Before and after contrast, value should be quantified, and focus must be put on advantages by means of the starting point described in the first step. Afterwards, teams can carry out a comprehensive assessment of the new situation and status in comparison to the starting point. Denoting the major issues recognized by manufacturing processes, some recommended metrics comprise cost of power, cost of manpower, production volume manpower required, productivity, etc. (Frost and Sullivan, 2017)

**Step 4: Replication of Prototype**

After confirming the information, the innovative smart manufacturing prototype can be deliberated a success when objectives of the project are fulfilled. Now that smart manufacturing prototype for the pilot set of devices and sensors, the subsequent stage includes spreading the arrangement to extra lines and machines (Frost and Sullivan, 2017).

Dealing with complexity: The vendor or developer of the practical system should be capable to develop an all-inclusive Industry 4.0 application, intended to fulfil prolonged metrics and objectives, and deployed in a step by step method so that processes are not disturbed.

Data: Growing the numbers of points of data, machines and associated sensors means that the data volume will upsurge intensely. One method is to employ cloud to surge storage and computing capability to match the novel increased needs.

Security: The upsurge in data in centrally-situated servers calls for greater security measures to protect and safeguard information, a vital resource for any firm. Security of data will have to guarantee that all the data is effortlessly accessible to authorized personnel, while being insulated from attackers.

**Step 5: Total rollout**

This last stage intends to attain additional visibility and efficiency by expanding Industry 4.0 linked systems outside the factory into the larger eco-system. By spreading data and communications accessibility to associated partners in supply chain, Industry 4.0 systems can link information silos in a unified SC. This allows an incorporated flow of work that is more effective whereas also agile to requirements of business (Frost and Sullivan, 2017).

Spreading Industry 4.0 to associated manufacturing units: The eventual objective would be to link several manufacturing units to attain thorough advantages from smart manufacturing systems. Industry 4.0 offers capability to see the bigger picture. As more machines are linked to the system, more information will be composed from manufacturing. This offers supervision with a combined assessment of all processes and a whole picture of manufacturing to support enhanced making of decisions. These could bring about optimized manual procedures to predict fault or to enhance competence and avert down time.

Improvement of Process by learning from one team: When all systems are integrated onto a single combined platform, procedures applied by teams that display effective metrics and best level of practice can additionally be analyzed, implemented and shared into other manufacturing firms internationally. Likewise, steps to solve problems and to address issues can be taken, implemented and shared.

Figure 1: Step by step method to implement smart manufacturing Industry 4.0

1. Challenges During the Implementation of smart manufacturing Industry 4.0

There are several challenges that manufacturing industries might face during the implementation smart manufacturing Industry 4.0. The main ones are: the new skills required; data security; and investment needs.

***Challenge 1: New skills required***

Rapid technological change, robotics, big data, artificial intelligence and connected objects offer new possibilities for manufacturers. But they also bring their challenges to the manufacturing industry. For example, in Quebec, manufacturing industry is at risk which represents nearly 800,000 direct and indirect jobs (Stock and Seliger, 2016). In order to successfully transition to Industry 4.0, the manufacturing company must examine the new skills that are required and the need for qualified personnel.

The most sought-after industry skills in 4.0 are Data management (data management); Data security (data security); Human-machine interaction (human-machine interaction); The user interface design (user interface design); Software development (software development); The programming (programming); Science data (data science); and the analytical (analytics) (Lee et al., 2014).

The major challenge facing the company is to train employees and recruit new resources. It's about finding the most appropriate approach for the company to successfully reconfigure the value chain and maintain or build on its competitive advantages.

Studies conducted in Germany and the United States have shown that for the vast majority of industrial employees, the skills required for Industry 4.0 are not present. Quebec is facing the same thing (Lee et al., 2014; Kang et al., 2016).

***Challenge 2: Data security***

Data security is a concern for all companies that have decided to switch to Industry 4.0. The multiplication of data and systems in the company highlights the importance of the computer security aspect. When technologies were connected to the internal network and centralized in the same building, securing everything was easier. The arrival of a multitude of connected objects, often relocated and accessible via the Internet, now imposes the management of cyber security (Schmidt et al., 2015).

It is therefore essential to integrate cyber security elements into the implementation of the company's IT infrastructure.

***Challenge 3: Investment needs***

Novel technologies are constantly related to investments. Industry 4.0 especially signifies a basic change for companies that require considerable funding. Unfortunately, most companies lack such vast amount of funds and fail to implement in Industry 4.0 (Anderl, 2014).

1. Recommendations for the effective implementation of smart manufacturing Industry 4.0

The following recommendations can be useful for the effective implementation of smart manufacturing Industry 4.0

* 1. Train Employees in Industry 4.0

Continuous training, flexibility, growth and accelerated changes can be key to the success of tomorrow's businesses. German companies have decided to focus on continuing education for their employees to ensure their qualification for Industry 4.0 (Crnjac et al., 2017). Training resources internally is a much more accessible approach to begin the transition to Industry 4.0. However, this is not enough to successfully implement the factory of the future.

Workers are dealing with complex technologies that are evolving very quickly, and manufacturing companies need, more than ever before, specialized technical profiles. Many companies are finding innovative solutions to their workforce challenges.

7.2 Addressing Investment Concerns

Manufacturing SMEs must make significant investments, ranging from 7% to 9% of their turnover, to integrate new digital technologies (Kang et al., 2016). Thus, the development of an "Industry 4.0" strategy and a digital plan is a must for SMEs who want to make better investment decisions for the acquisition and integration of new technologies.

The digital plan must be embedded in the strategic planning of the organization. Its objectives will be to optimize the current tools, draw up the plan for acquiring future technologies and ensure their cohesion and integration, all considering the business model.

* 1. Improving efficiency

The managers should get a clear image of operational standing, particularly across multiple lines. Important info about facilities, processes and equipment should be readily accessible across the firm. The implemented Industry 4.0 system should be able connect sensor data and operations across several lines and machines.

1. Conclusion

In the past, manufacturing was restricted to a sequence of procedures or a process through which raw resources is transformed into end products. However, this is changing quite a lot now particularly with the advent Industry 4.0 which uses computerized controls, sensors, information technology, intelligent motors, production management software and to handle all specific stages or operations of a manufacturing procedure. Additionally, the convergence between human intelligence and machine-gathered data can advance enterprise-wide management and plant-wide optimisation objectives, counting considerable upsurges in environmental sustainability, financial performance and worker safety.

This is important as the manufacturing sector has a significant impact on the economic vitality of a country. Therefore, key players in the business community should be mobilized to accelerate manufacturing innovation. The Industrial Revolution 4.0 will bring profound changes to our society, including an important digital shift in the manufacturing sector. To survive, manufacturing companies must rely on the training and know-how of their employees, the integration of new technologies, robotization and automation. Competition is strong on the world stage, and several industrialized countries are in the running. To stay ahead of and even ahead of their competitors, manufacturing firms need to be more competitive and more productive. In a nutshell, they must innovate to deliver high value-added products, reduce costs and lead times, maximize employee skills and extend the life cycle of their products.

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