cloud computing, additive manufacturing, and others to propel more responsive, versatile and interconnected establishments to make more enlightened decisions. Industry 4.0 carries with it seemingly endless options for technological investments and endless opportunities [5].

It's not that companies will go out of business if they don't take advantage of the new technologies," says Martin Strutt, region director of manufacturers' organisation the EEF. "But it will be difficult for them to contend with organizations that do." A report from Future Market Insights predicted smart factories will make US$215 billion by 2025. That's huge up from $ 51.9bn in 2014. According to General Electric, the smart factory concept could be worth $10-15 trillion to Global Gross Domestic Product over the next 20 years [6].

Western civilization has passed through three stages of the industrial revolution, and the fourth revolution is in progress [9]

The Industry 4.0 is based on the concept of factory of future, where the equipment are integrated with workers through cyber-physical systems (CPS). Industry 4.0 is a new level of establishments that operates, manages and controls the whole value chain of personalized products to satisfy customer needs. The most important component in Industry 4.0 is Digitalization because it enables to connect technology with human beings [7]. Fig. 1 shows the technology aspects of four industrial revolutions.

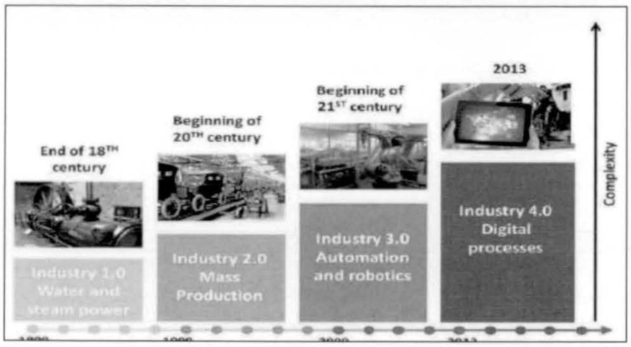

Fig. 1. Four industrial revolutions [7].

Industry 4.0 covers three fundamental aspects (Shown in Fig. 2.) [7] [12]:

i) Digitization and increased integration of vertical and horizontal value chains: Development of custom products, customer's digital orders, automatic data transfer, and integrated customer service systems.

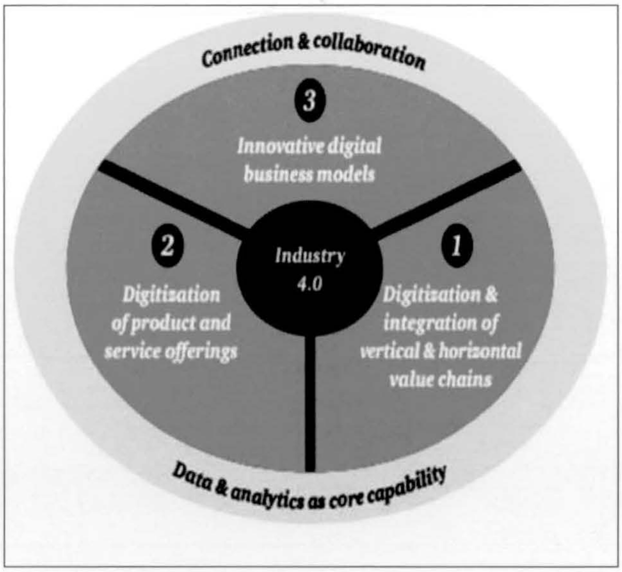

Fig. 2. Fundamental aspects of industry 4.0. [4] [7].

ii) Digitization of product and service offerings: Complete descriptions of the product and its related services through intelligent networks.

iii) Introduction of innovative digital business models: The high level of interaction between systems and technology opportunities develops new and integrated digital solutions. The basis of Industrial Internet of Things is the integrated and concurrent availability and control of systems across the organisation.

Industry 4.0 enables complete customization which gives very high flexibility for manufacturers to meet changing requirements from their consumers, who are increasingly favoring more customizable and flexible outputs over standard product offerings. For example, the mass customization program 'miAdidas' initiated by global leading sports brand Adidas, has been running from several years. This initiative allows sportsman's to customize and personalize their sports footwear to fulfill their styling and performance needs. In their effort to bring manufacturing closer to their customers in the respective countries, Adidas has also planned to open its first fully automated factory in Germany. Such technologies have also helped manufacturers in minimizing lead time for prototype development. As a result, companies are able to speed-up their time to market [10]. The difference between traditional manufacturing and Industry 4.0 manufacturing is shown in Fig.3.

Fig. 3 lists down transitions expected across the business models with the implementation of Industry 4.0. Industry 4.0 represents a paradigm of a more dynamic, agile, and automated manufacturing shifts from the previous era of inflexible, efficiency-concentrated and labor intensive manufacturing. It marks a shift of focus from large quantity production of standard products to mass customization, enabled by amenable production and shorter lead times. Similarly, a transition will take place from large-scale factories specialized for a product to smart factories with high-tech equipment capable of producing multiple products at competitive cost. Flexibility will also be manifested in the capacity to function remotely using techniques such as augmented reality.

	Traditional Manufacturing	Industry 4.0 Manufacturing
PROCESS	Rigid and manual	Agile and automated
PRODUCT	Standardized	Personalized and customized
SCALE OF FACTORIES	Large factories at centralized locations	Small factories at decentralized locations
SUPPLY CHAIN	Stock based planning	Dynamic and predictive
SUCCESS METRIC	Low cost, high efficiency	High return on capital employed (ROCE)
CLIENT RELATIONSHIP	Low and indirect	High and direct

Source: Roland Berger

Fig. 3. Industry 4.0 what is changing for companies? [11].

The success metrics for organizations will also changes from achieving low cost effectiveness to obtaining higher returns on capital investment. Profitability is increased by Industry 4.0 by facilitating greater customization, minimizing the complexity cost and reducing labor costs. Simultaneously, it enables to high return on the capital invested by allowing asset utilization and greater flexibility.

2. Smart Factory

The introduction of Internet of Things devices to the factory is one of the most effective ways to begin the transformation into a smart factory. 'Smart' in its simplest manner is about collecting data from the manufacturing methods, transforming that data into information and then

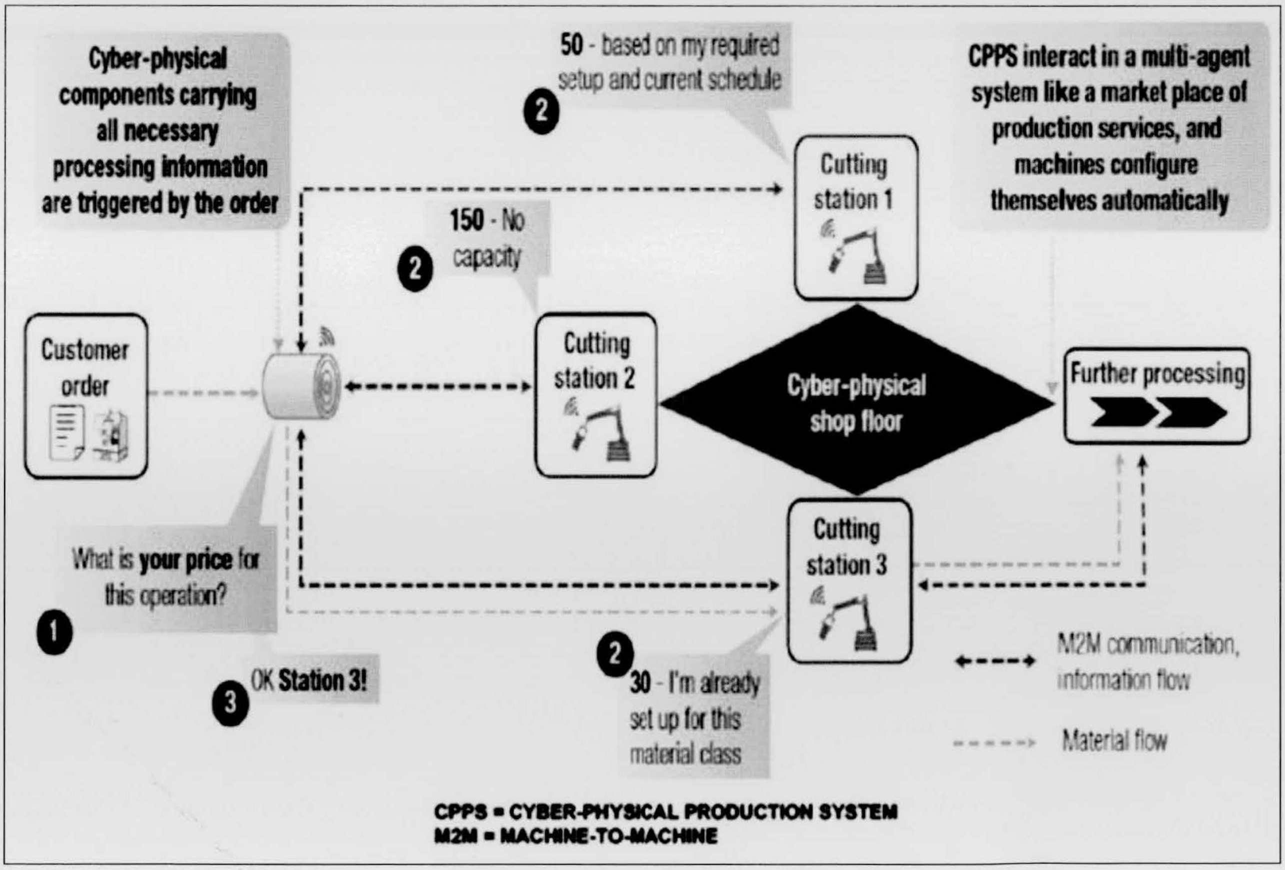

Fig. 4. Schematic diagram of a typical smart factory [4].

acting on that information [20].

"The smart factory is a versatile system that can self optimise functionality across a wider network, adapt itself to and learn from new conditions in real or near-real time and operate full manufacturing processes autonomously" [4].

The factory of the future works autonomously and can perform diagnostics necessary to detect and fix any malfunctions without needing to stop the entire manufacturing. While upgrading to an Industry 4.0 driven factory is an objective that many companies are searching to achieve, it is not always clear to know what creates an intelligent factory and how to start this transformation.

The introduction of Internet of Things devices to the factory is one of the most effective ways to begin the transformation into a smart factory. However, companies must be careful that they don't rush into things head first.

3. Challenges for Industry 4.0

The current Indian development system is unsustainable as the main (agricultural) industry only provides 12% of GDP but employs 51% of the workers. The secondary (industry-related) sector contributes 16% of the GDP and employs about 22%. Whereas service sector (tertiary) employs only about 27% of the working population and contributes 55% the GDP.

The ministry of heavy industries and public enterprises provide supports to facilitate four centres in the country to help SMEs materialize Industry 4.0. Bengaluru is in the process of setting up India's first smart factory. This smart factory is driven by the Internet of Things (IoT) and data exchange. This Smart Factory is being established with financial assistance from The Boeing Company at the Centre for Product Design and Manufacturing (CPDM) department of Indian Institute of Science (IISc).

The goal of Government of Andhra Pradesh to make the state into an Internet of Things (IoT) hub by 2020. With the participation of the private sector, the state government plans to set up 10 IoT hubs that will create 50,000 direct jobs in different IoT verticals. Since more than 80% of the manufacturing industry in India is in the MSME sector, the implementation of Industry 4.0 is a major challenge. The following are the key challenges listed to implement the Industry 4.0 in India [4] [5] [7] [9] [10] [11] [12] [13] [16] [17] [18] [21]:

(i) Investment: Where do enterprises spend their capital? A huge issue for many enterprises who wish to implement Industry 4.0 is a buying strategy that is less than clear for a lot of them. As a result, there are often unclear economic incentives for development and organizations find themselves having to spend over the odds to implement these new initiatives. Such a technological transformation will require a significant investment in new technology. For such a transformation, the decision will be taken by the highest management level. Even then, it is necessary to calculate return on investment and take the risks seriously. In addition to the requirement of huge capital, such transformation will isolate small businesses and might lose their market share in the future.

To solve this, organizations have to put a strategy to ensure that their business works with industry 4.0, also has a clear plan as to why they're upgrading, and select the best technology at an affordable cost.

(ii) The workforce: Optimizing Talent: Bringing together smart factories and manufacturing automation will bring remarkable levels of effectiveness and speed to a business, but the drawback of this is that many organizations will see a workforce that will be unused to the new developments taking place, and ill-equipped to adapt to them. While it remains early to make a judgment on working circumstances with the global implementation of Industry 4.0, it is safe to say that workers will need to acquire different or an all-new set of skills. This may help to increase the employment rates but it will also isolate a big sector workers. The sector of workers whose work is to perform repetitive tasks will face a challenge in keeping up with the industry 4.0. Different forms of education must be initiated, but it still doesn't solve the problem for the experienced workers. This is an issue that might take longer time to solve.

To solve this, organizations repurpose their workforce to suit the new demands of their business. Whether it's training them to work alongside machines with virtualization or simulation programs, or readjusting the employees for work in an entirely different sector.

(iii) Standardisation: Integrating Software, Hardware, Operating Systems and standards play an important role in forming industry 4.0. Developments and coordination of standards and proposals will promote efficient development of industry 4.0 infrastructures and applications, services and devices. There is some confusion with companies trying to innovate as to which standards will be adopted in the next five years. A huge challenge to overcome will be to derive a standardized system that works for all parties and allows for both horizontal and vertical integration, and results in maximum value for both present and future investments. In today's network world, global standards are more relevant than local agreements.

In order to fix this problem, companies should decide to facilitate the law changes in collaboration with government and bring everybody together in one room to thrash out the details. By establishing a standard practice with respect to the hardware and software available, companies should match their suitable operating systems for their implemented technology, or call upon technology partners for the development of software that facilitates cross-platform operation.

(iv) Data security: How will enterprises keep their data safe? Medium and Small scale organizations are primed to benefit the most from Industry 4.0, but this represents a quandary. Compared with traditional manufacturing data security, privacy issues of Industry 4.0 become more prominent. Much information includes privacy of users, so that protection of privacy becomes an important security issue in industry 4.0. Because of combination of things, services and networks, security of Industry 4.0 needs to cover more management objects and levels than traditional network security. Existing network security architecture that is designed from the prospective of human communication may not be suitable and directly applied to Industry 4.0. The existing security mechanism will block logical relationship between components in Industry 4.0.

Industry 4.0 needs low cost and M2M – oriented technical solutions to guarantee the privacy and security. In many cases, the security of a system has been considered as general feature. Related research shall focus on privacy control. The sensors or devices used should be low cost, low latency and energy efficient cryptography algorithms and related flexible hardware will be essential for sensor or device.

(v) Technical Challenge: Technology for industry 4.0 can be complex for various reasons. Firstly there are legacy heterogeneous architecture in the existing networking technologies and applications, For example different environments and applications requires different networking technologies and the ranges as well as other characteristics of cellular, wireless local area networks and RFID technologies are much different from each other [5][21]. Secondly communication technologies including fixed and mobile communication systems, power line communications, wireless communication technologies for both fixed and mobile devices either simple or complicated should be low cost and with reliable connectivity. Others include what kind of security solutions are appropriate, there are thousands different applications and so on.

To summarize, complexity and alternative technologies may introduce unnecessary competition and deployment barriers in markets may also introduce unnecessary dependency of systems with communication mechanisms. This may block the migration of IoT systems to the most economical and efficient platforms.

(vi) Real-time constraints: Industry 4.0 requires some amount of real-time performance if they are going to control machines and factories [22]. Industrial control systems require real-time reaction, making changes to the systems very difficult. Downloading the required data from the cloud for plant system operation requires the system of the plant to access "big data" in real time in cyberspace. Loading accessible software versions on the malware scanners and antivirus programs of the system could affect the process performance. Any real-time interaction must be quick enough to promote the demands for system automation. For example, Safety Instrumented Function (SIF) for turbine over-speed protection may need to react within 10 ms on demand.

(vii) Modularization: Modularization is one of the key developments in new machine design. Unlike their monolithic components, modular machines are designed from standardized parts or sub-systems that can be integrated into various aspects to execute a variety of desired tasks. This can save a lot of effort in planning, designing and commissioning such devices as well as allowing quick reconfigurations to fulfill varying manufacturing requirements.

Industry 4.0 encourages modularization system. Plants will comprise of smart modules that can be integrated like bricks within the automation structure. The idea of modularization may conflict with the performance-based strategy needed to design and develop a security system. Functional safety and cyber security standards constitute performance based strategy because specialists in this sector think that the plant-specific risk needs to be evaluated first and then the risk-reduction steps needed to fulfill specified tolerable levels are implemented.

(viii) Operation and maintenance: The amount of sophistication required to design, control and security instrumented devices for Industry 4.0 will raise significant challenges for manufacturers. Much attention must be given on the competency of the software developer, operators, designer and maintenance personnel across the entire safety lifecycle during the factory design. The factory design process involves the making of cyber- physical components where field devices are programmable and linked to the Internet and modularized (different device components from different suppliers) and also wireless connectivity feature as a standard configuration. Traditional sensors currently enable easy diagnosis and timely repair because vendors don't need real-time online assistance and operators understand how to run their equipment using the system information presented in graphics and alarms. Industry 4.0 systems operation and maintenance will require more in-depth assistance from suppliers and third parties as the complexity of automation increase the need for expert level diagnostics. Operators won't be able to carry out all tasks and supporting maintenance activities by themselves [21].

4. Opportunities for Industry 4.0

India is very much eager to implement Industry 4.0 and several measures have been adopted. According to Indian Brand Equity Foundation (IBEF), by 2025, the Government of India intends to raise the production sector's contribution from the present 16% rate to 25% of Gross Domestic Product (GDP). India is also prepared to face global competition by undertaking the Make in India and skill development programs. It is all set to lead the world with Smart Manufacturing. The following are the opportunities for industry 4.0 in India:

(i) Young Population: Employers want to invest in young people and see them as a future asset. With an average age of less than 30 and nearly 10 lacks individuals joining the workforce every month, India offers the ideal atmosphere for first-time young job seekers to pursue opportunities in emerging fields of interest in the Indian manufacturing industry – consumer electronics, automotive, aeronautics and aerospace.

(ii) Favorable Policies: The 'Make in India' program is India's plan of action to encourage Indians to create products for the world market. India has the resources, policy and workforce in place. What is needed is experts from foreign industries to crank-up a manufacturing revolution in the areas of automobile and aerospace. Relaxed FDI policies and better protection for company's intellectual property, coupled with industry-favorable government policies have created competition amongst Indian states to attract foreign direct investments in the manufacturing sector. With the increase in World Bank's Ease of Doing Business ranking is also a welcome sign that first time foreign investors are positive about the country's growth potential.

(iii) Skilled workforce: With a strong high school and university ecosystem, Indian students are sought after by multinationals all over the world. Fast Changing times and a slow adaptive to education system however, have rendered man qualities gained in academics Redun- dant in today's work environment. The efforts of governments and private industry to set up reskilling and skill upgrading centres to raise employability.

(iv) Large population base ready to go digital: The emphasis on ' Digital India ' and the government's int ervention in 2016 to suppress uncounted cash from the sy stem through a huge demonetization effort are all pushing Indians too quickly to adjust to the use of digital payments. Rapid growth is set for this sector. Indian government has also begun attempts to link the nation digitally by providing a Unified Payment Interface (UPI), a zero-cost payment gateway and cash enterprises.

5. Industry 4.0 Benefits [15]

Industry 4.0 brings in the following benefits:

(i) Lower Cost.

(ii) Additional Revenue.

(iii) Enabling Industrial Companies to optimize customer relationship.

(iv) Transparency in the production process.

(v) Clarity on the status of all aspects of production system in real time.

(vi) Industrial companies that successfully implement Industry 4.0 no longer need to choose between focusing on a better top or bottom line. They can improve both at the same time.

(vii) Logistics processes become leaner.

(viii) Reduced inventories.

(ix) Standardization of maintenance processes.

(x) Cent percent traceability

6. Conclusion

Industry 4.0 creates a newer manufacturing environment and knowledge economy. Industry 4.0 encompasses many technologies such as IoT, WSN, Communication technologies, low power electronics etc. The development of Industry 4.0 in India exposed many challenges that includes lack of fundamental theory supporting, immature standards, Technical challenges and lack of investment. With these challenges, India has several opportunities for industry 4.0 implementation. Such opportunities are large young population ready to go for digitalization, central government policies like Make in India and skill development, significant experience in developing IT- related infrastructure, Companies collaboration with educational institutes etc.

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A review on challenges and opportunities for implementing Industry 4.0 in India*

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**Presented in 1st National Conference on Smart Manufacturing & Industry 4.0 (NCSMI4) at Central Manufacturing Technology Institute (CMTI), Bengaluru, during May 30-31, 2019.*

ABSTRACT

Keywords:
Industry 4.0,
Internet Of Things,
Smart Factory,
Cyber-Physical Systems

The globalization and the competitiveness are enforcing organizations to readdress and innovate their production processes. The world is entering a new era of industrial emanating technology in automation and data exchange through the use of Internet of Things called fourth technological revolution or Industry 4.0. It represents the amalgamation of tools already used in the past such as big data; cloud, robot, 3D printing, simulation, etc. are now connected into an internet to transmit digital data. For the implementation of this new paradigm, there are many opportunities and also many challenges. This paper highlights brief introduction on challenges and opportunities for implementation of Industry 4.0 in India.

1. Introduction

An industrial revolution can be defined as a disruptive leap in the industrial process [8], a development that produces fundamental transformations in the society and the economy [9]. First industrial revolution started in 1784 with the introduction of the first machines that used steam for power. Many people worried and opposed because use of machines may reduce the requirement of manual workers. The second industrial revolution, which initiated around 1870, started the production system which manufactured the components in large scale by adopting assembly line production system which used electricity as source of power [1]. The third industrial revolution which switches the technology driven by mechanical and analog electronic to digital electronics, began with the introduction of the robotics and automation in the year 1969 [2][19].

Efficient machines and robots were used in automation of different tasks in industries in which the computer system and automation is widely used to manufacture parts. Finally in the year 2013 the Industry 4.0 or Fourth industrial revolution conception is formed on the cyber physical systems, cloud computing and internet of things to manufacture the components [3]. In recent years, manufacturers and vendors used innovational technologies to enhance the quality of goods and services of their organizations. This is because, the industry is shifting towards complete digitization and the intelligence of production processes to ensure high efficiency. To attain these grails, it is essential to implement new technologies for the automation of industrial processes. These ideas are the backbone of the fourth industrial revolution called "Industry 4.0". This Fourth industrial revolution was established in Germany in 2013 but is outspreading rapidly in China, Europe and in the whole world. This new work model focuses on the integrated man-machine approach through "sustainable" production. [7].

INDUSTRY 4.0 has enlarged the capabilities of digital revolution and increased its significance to the organization. Industry 4.0 combines and connects the Internet of Things, digital and physical technologies; robotics, artificial intelligence,

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