Industry 4.0: High-tech Strategy for Future Manufacturing Industries

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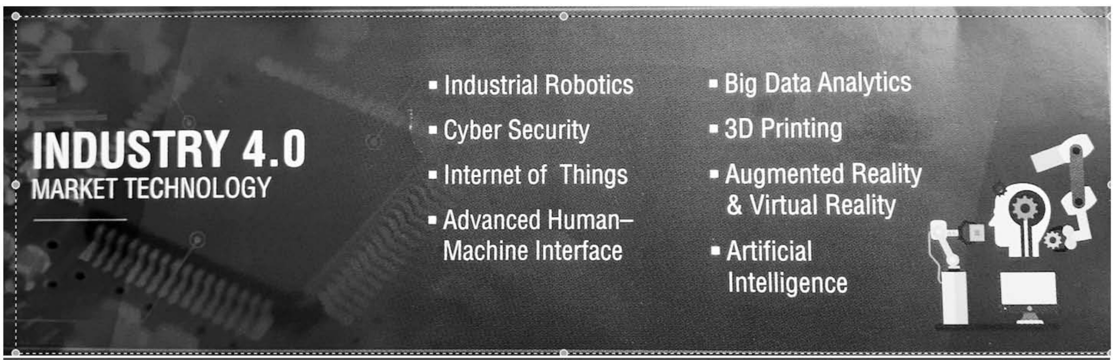


Abstract -- **Industry 4.0 connects embedded system production technologies and smart production processes to pave the way to a new technological age which will radically transform industry and production value chains and business models.**

Previous industrial revolutions liberated humankind from animal power, made mass production possible and brought digital capabilities to billions of people. Fourth Industrial Revolution is, however, fundamentally different. It is characterized by a range of new technologies that are fusing the physical, digital and biological worlds, impacting all disciplines, economies and industries, and even challenging ideas about what it means to be human.

Industry 4.0 fosters what has been called a "smart factory". Within modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the Internet of Things, cyber-physical systems communicate and cooperate with each other and with humans in real-time both internally and across organizational services offered and used by participants of the value chain.

Keywords: Smart factory, Cyber physical systems, Internet of things, Industrial internet of things, Cloud computing, Cognitive computing, Artificial intelligence.

I. INTRODUCTION

INDUSTRY 4.0 triggers a staggering effect by transforming the manufacturing and production processes in industries. In other words, Industry 4.0 will play a significant role in transforming traditional companies into Smart Factories with the help of Internet of Things (IoT) and Cyber Physical Systems (CPS). A decentralized approach takes great importance in Industry 4.0, which emphasizes independent management of processes and smart objects throughout the network; by doing so, real and virtual worlds collaborate on the processes [1]. The development of integrated processes and human machine interaction stimulate complexity and agility but also data transmission between value chains. With the help of Industry 4.0, industries will gain operational efficiency both in time, cost and also productivity. Building the infrastructure of IoT offers shared platforms via cloud systems between partners in supply chains; therefore business processes can be optimized [2].

Industry evolution with key developments is depicted in Fig.1. *Industry 1.0:* refers to the first industrial revolution. It is marked by a transition from hand production methods to machines through the use of steam power and waterpower. The implementation of new technologies took a long time, so the period which this refers to it is between 1760 and 1820, or 1840 in Europe and the US. Its effects had consequences on textile manufacturing, which was first to adopt such changes, as well as iron industry, agriculture, and mining though it also had societal effects with an ever stronger middle class.

Industry 2.0: the second industrial revolution or better known as the technological revolution is the period between 1870 and 1914. It was made possible with the extensive railroad networks and the telegraph which allowed for faster transfer of people and ideas. It is also marked by ever more present electricity which allowed for factory electrification and the

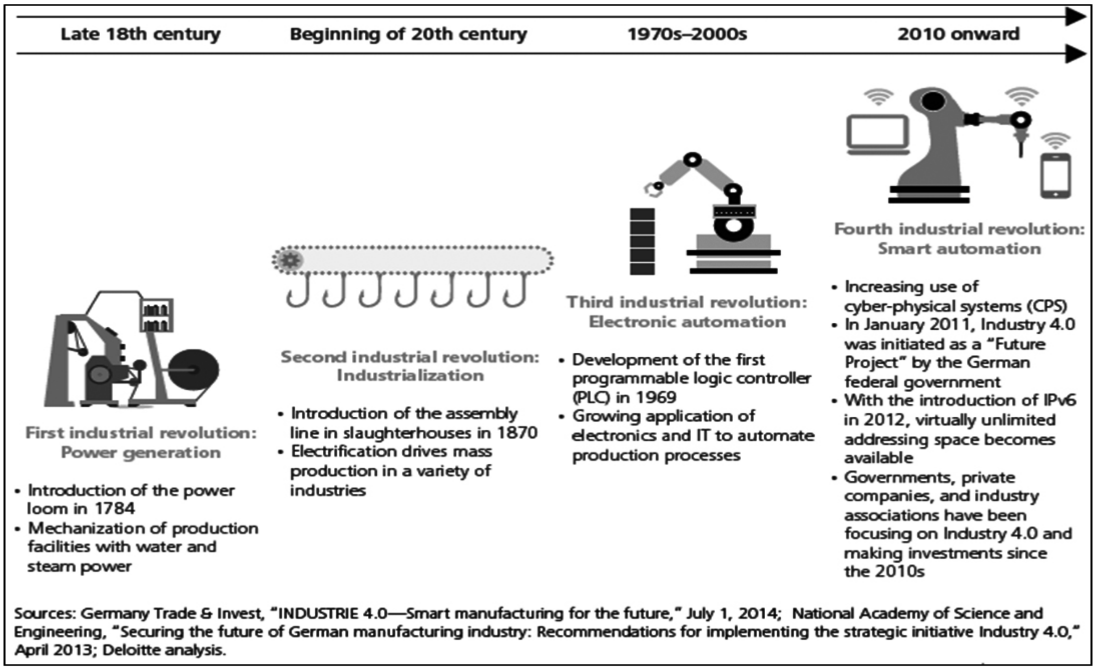


Figure 1. History of industrial revolutions.

modern production line. It is also a period of great economic growth, with an increase in productivity. It, however, caused a surge in unemployment since many workers were replaced by machines in factories.

Industry 3.0: the third industrial revolution occurred in the late 20th century, after the end of the two big wars, as a result of a slowdown with the industrialization and technological advancement compared to previous periods. It is also called digital revolution. The global crisis in 1929 was one of the negative economic developments which had an appearance in many industrialized countries from the first two revolutions.

Industry 4.0: is not from the industry but is supported by the Government. In 2013, German government memo widely recognised as one of the first times that 'Industrie 4.0' was mentioned. The high-tech strategy document outlined a plan to almost fully computerise the manufacturing industry without the need for human involvement. The idea really hit the headlines when Chanceller Angela Merkel spoke glowingly of the concept in January 2015 at the World Economic Forum in Davos, calling 'Industrie 4.0' the way to "deal quickly with the *fusion of the online world and the world of industrial production."* The characteristics given for the German government's Industry 4.0 strategy are: strong customization of products under the conditions of highly flexible (mass-) production. The required automation technology is improved by the introduction of methods of self-optimization, self-configuration, self-diagnosis, cognition and intelligent support of workers in their increasingly complex work.

Unlike the previous industrial revolutions, Industry 4.0 is unfolding at an exponential pace… rather than a linear one. The concept of Industry 4.0 has gained great importance in recent years. The increase in usage of computerized systems after the 3rd Revolution, Industry 4.0 deals with creating more digitized systems and network integration via smart systems. Through Industry 4.0, smart systems would enable replacement of the human-being in certain tasks and ease the working environment. Previous industrial revolutions liberated humankind from animal power, made mass production possible and brought digital capabilities to billions of people. This Fourth Industrial Revolution is, however, fundamentally different. It is characterized by a range of new technologies that are fusing the physical, digital and biological worlds, impacting all disciplines, economies and industries, and even challenging ideas about what it means to be human.

According to a 2012 WEF report, manufacturing has continued to be a huge driver of prosperity - particularly in developing nations - which have seen significant growth in their manufacturing sector. It offers the manufacturing process of aircraft manufacturer Boeing's 787 Dreamliner as an illustration of the concept it calls "disaggregation" - and provide a stark illustration of both the complexity and international nature of modern manufacturing.

The report says that Boeing's Dreamliner is manufactured with components from 287 suppliers across no less than 22 countries. It is such a great model of modern, complex international and interdependent manufacturing that it was also offered in 2016 as an example of global supply chain complexity by the U.S. Chamber of Commerce.

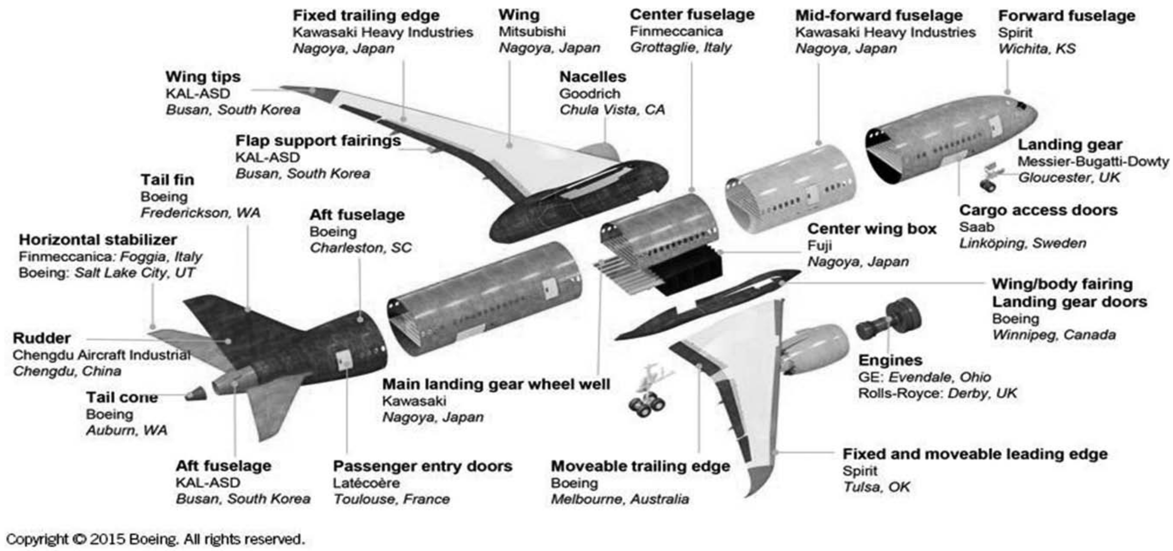


Figure 2. Boeing's Dreamliner is manufactured with components from 287 suppliers across 22 countries.

Modern manufacturing is a highly interdependent, complex (and often international) undertaking. Manufacturers are vulnerable to any single point of failure along the global supply chain.

II. BASIC COMPONENTS OF INDUSTRY 4.0

Depending on where a manufacturer's focus lies, it may pursue different opportunities within the manufacturing value chain. Indeed, both operating and growing the business map to different areas across the value chain. The prioritization of operations versus growth can serve as a guide as to which areas of the value chain merit the greatest attention.

For example, the first stage of the manufacturing value chain focuses on R&D and design, areas where Industry 4.0 technologies can accelerate and improve the design cycle, reducing time to market, and linking design to smarter products. Stakeholders most impacted by Industry 4.0 at this stage will likely be design engineers. At the other end of the value chain, new or incremental revenue—and business growth—can emerge from Industry 4.0 applications in the form of new and improved products and services. Stages at the middle of the value chain—planning, factories, and support—can use Industry 4.0 technologies to transform operations in various ways.

Each of these uses of connected technologies includes its own information value loop, in which manufacturers may encounter bottlenecks that may impede optimal outcomes. In these cases, it is important to identify technology solutions that can address each bottleneck, a topic we will explore at length in subsequent research.

a) Business Operations:

Planning: Predicting changes and responding in real time. When planning for production, manufacturers often encounter a host of uncertainties across the manufacturing value chain. IT (Information Technology) and OT (Operational Technology) can support several transformations in this area. Demand sensing and planning using IT (for example, sensors, signal aggregation, optimization, and prediction) enable manufacturers to gather data throughout the value chain. Data can be analysed to uncover patterns, track movements, and, ultimately, understand what customers want so they can better plan to provide it at the right time and place.

Factory: Creating a digital link between operations and information technology. Perhaps no other segment better encapsulates the physical-to-digital transformation inherent in Industry 4.0 than the intelligent factory. The industry 4.0-enabled factory utilizes physical-to-digital technologies such as augmented reality, sensors and controls,wearables, and the Internet of Things to track movement and production, monitor quality control, and manage the tooling life cycle, among other capabilities. In this way, Industry4.0 on the factory floor can enable enhanced capability effectiveness, production asset intelligence, and activity synchronization and flow. Learning the causes behind a failure can enable manufacturers to more effectively address the root of the problem, rather than its symptoms.

Support: Automating and scaling aftermarket operations. Once a part or product has been developed, manufactured, shipped, and sold, Industry 4.0 technologies can impact support in at least three keyways namely:

- Aiding productivity and quality of field repair,

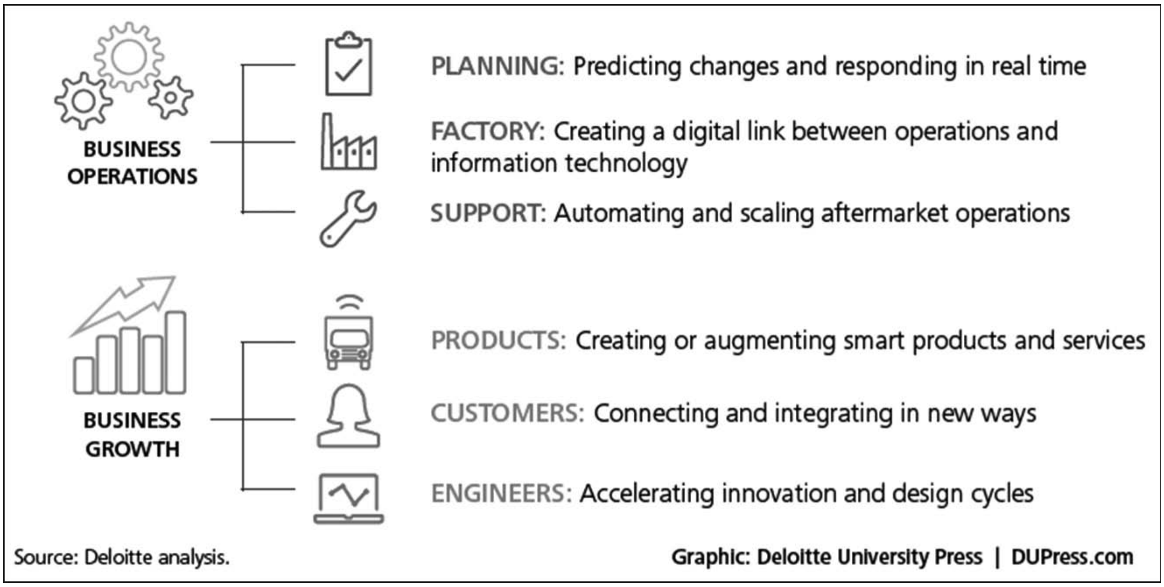


Figure 3. Basic components of industry 4.0.

- Predicting part, product, or service failure,
- Responding in a timely, accurate, and effective manner so that the causes behind a failure enable manufacturers to more effectively address the root of the problem.

b) Business Growth:

Products: creating or augmenting smart products and services. Products in the age of Industry 4.0 run the technological gamut. The use of IT such as sensors and wearables and OT such as advanced manufacturing in the form of additive manufacturing, advanced computer numerical control, and robotics can enable product improvements in various ways like making already existing products smarter, developing completely new products and services. Indeed, manufacturers are already using advanced OT (such as additive manufacturing) and advanced IT (in the form of scanning and embedded sensors) to create new products and improve upon old ones—delivering new levels of value to customers, along with new data products.

Customers: Creating and integrating in new ways: Data and information gathered through intelligent products and services can enable manufacturers to better understand their customers. Indeed, customer experience in the age of Industry 4.0 is driven not just by the physical object, but also by the data and information—and analytics—that make the customer's interaction with that object more transparent and impact the customer-manufacturer interplay in various ways like market and sell products more intelligently with customer feedback. The information gathered from customers can be used to price and sell products and services more intelligently. For example,Uber uses data from its drivers and customers to power an algorithm that calculates surge pricing, a dynamic pricing model meant to adjust prices upward when demand is high. IT and OT can potentially drive product and service improvements, as well as more intelligent asset utilization. Further, this data can work both ways: Not only can information be sent to the manufacturer and its partners, but also back to the customer via smart apps that offer user-experience enhancements.

Engineers: Accelerating innovation and design cycles. At the start of the manufacturing value chain, products are developed and designed. Various Industry 4.0 technologies—notably OT technologies such as additive/advanced manufacturing and IT, digital tools such as CAD, and simulation—can come into play to impact the process in several keyways like better link design to product need and intelligence and improve the overall effectiveness of engineering.

The use of digital-to-physical manufacturing technologies such as additive manufacturing in rapid prototyping can speed up the design process as well as the production of end-use products, thus reducing supply chain dependencies.

Industry 4.0 technologies can drive improved engineering effectiveness via digital design and simulation. This can take the form of virtual product development and testing. These tools can also take the form of open source innovation, allowing freelance design to improve products through open sharing of intellectual property.

What all these components have in common, is that Data and Analytics are their core capabilities. "Industry 4.0" is driven by:

Digitization and integration of vertical and horizontal value chains: Vertically, Industry 4.0 integrates processes across the entire organization for example processes in product development,manufacturing, logistics and service whereas horizontally, Industry 4.0 includes internal operations from suppliers to customers plus all key value chain partners.

Digitization of product and service offerings: Integrating new methods of data collection and analysis for example through the expansion of existing products or creation of new digitised products, helps companies to generate data on product use and thus, to refine products in order to meet best the customers' needs.

Digital business models and customer access: Reaching customer satisfaction is a multi-stage, never-ending process that needs to be modified currently as customers' needs change all the time. Therefore, companies expand their offerings by establishing disruptive digital business models to provide their customers digital solutions that meet their needs best.

III. INDUSTRY 4.0 DESIGN PRINCIPLES

The design principles allow manufacturers to investigate a potential transformation to Industry 4.0 technologies. Based on the components above, the following are the design principles:

Interoperability: Objects, machines and people need to be able to communicate through the Internet of Things and the Internet of People. This is the most essential principle that truly makes a factory a smart one.

Virtualization: Cyber physical systems (CPSs, which is integration of physical world with internet) must be able to simulate and create a virtual copy of the real world. CPSs must also be able to monitor objects existing in the surrounding environment. Simply put, there must be a virtual copy of everything.

Decentralization: The ability of CPSs to work independently. This gives room for customized products and problem solving. This also creates a more flexible environment for production. In cases of failure or having conflicting goals, the issue is delegated to a higher level. However, even with such technologies implemented, the need for quality assurance remains a necessity on the entire process.

Real-Time Capability: A smart factory needs to be able to collect real time data, store or analyse it, and make decisions according to new findings. This is not only limited to market research but also to internal processes such as the failure of a machine in production line. Smart objects must be able to identify the defect and re-delegate tasks to other operating machines. This also contributes greatly to the flexibility and the optimization of production.

Service-Orientation: Production must be customer-oriented. People and smart objects/devices must be able to connect efficiently through the Internet of Services to create products based on the customer's specifications. This is where the Internet of Services becomes essential.

Modularity: In a dynamic market, a Smart Factory's ability to adapt to a new market is essential. In a typical case, it would probably take a week for an average company to study the market and change its production accordingly. On the other hand, smart factories must be able to adapt fast and smoothly to seasonal changes and market trends.

IV. INDUSTRY 4.0 TECHNOLOGIES

Industry 4.0 represents an integration of the IoT and relevant physical technologies, including analytics, additive manufacturing, robotics, HPC, artificial intelligence and cognitive technologies, advanced materials, and augmented reality, that complete the physical-to-digital-to-physical cycle.

Manufacturing leaders have the opportunity to develop improved operations strategies and to realize key business objectives based on the technologies they may choose to employ at various points in the manufacturing value chain. Some of the technologies that encapsulate the physical-to-digital-to-physical reach of Industry 4.0 are listed in Fig. 4.

"Industry 4.0" is an abstract and complex term consisting of many components when looking closely into our society and current digital trends. To understand how extensive these components are, here are some contributing digital technologies as examples:

- Mobile devices
- Internet of Things (IoT) platforms
- Location detection technologies
- Advanced human-machine interfaces
- Authentication and fraud detection
- 3D printing
- Smart sensors
- Big data analytics and advanced algorithms
- multilevel customer interaction and customer profiling
- Augmented reality/ wearables
- Fog, Edge and Cloud computing
- Data visualization and triggered "real-time" training.

Role of Big Data and Analytics: Modern information and communication technologies like cyber-physical system, big data analytics and cloud computing, will help early detection of defects and production failures, thus enabling their prevention and increasing productivity, quality, and agility benefits that have significant competitive value.

Big data analytics consists of 6Cs in the integrated Industry 4.0 and cyber physical systems environment. The 6C system comprises:

- Connection (sensor and networks)

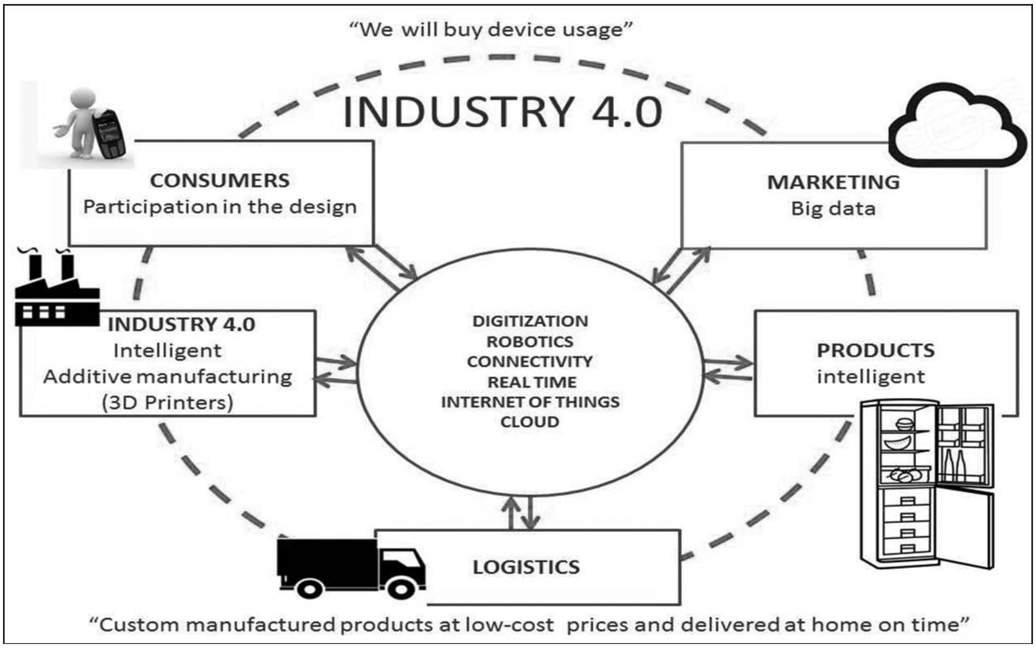


Figure 4. Industry 4.0 technologies.

- Cloud (computing and data on demand)
- Cyber (model & memory)
- Content/context (meaning and correlation)
- Community (sharing & collaboration)
- Customization (personalization and value).

In this scenario and in order to provide useful insight to the factory management, data has to be processed with advanced tools (analytics and algorithms) to generate meaningful information. Considering the presence of visible and invisible issues in an industrial factory, the information generation algorithm has to be capable of detecting and addressing invisible issues such as machine degradation, component wear, etc. in the factory floor.

V. ADVANTAGES OF INDUSTRY 4.0

Optimization: Optimizing production is a key advantage of Industry 4.0. A Smart Factory containing hundreds or even thousands of Smart Devices that are able to self-optimize production will lead to an almost zero down time in production. This is extremely important for industries that use high end expensive manufacturing equipment such as the semi-conductors industry. Being able to utilize production constantly and consistently will profit the company.

Customization: Creating a flexible market that is customer-oriented will help meet the population's needs fast and smoothly. It will also bridge the gap between the manufacturer and the customer. Communication will take place between both directly. Manufacturers won't have to communicate internally (in companies and factories) and externally (to customers). This fastens the production and delivery processes.

Pushing Research: The adoption of Industry 4.0 technologies will push research in various fields such as IT security and will have its effect on the education in particular. A new industry will require a new set of skills. Consequently, education and training will take a new shape that provides such an industry will the required skilled labor.

VI. CHALLENGES FACING INDUSTRY 4.0

Security: Perhaps the most challenging aspect of implementing Industry 4.0 techniques is the IT security risk. This online integration will give room to security breaches and data risks. Cyber theft must also be put into consideration. In this case, the problem is not individual, but can, and probably will, cost producers money and might even hurt their reputation. Therefore, research in security is crucial.

Capital: Such transformation will require a huge investment in a new technology that doesn't sound cheap. The decision to make such transformation will have to be at CEO level. Even then, the risks must be calculated and taken seriously. In addition, such transformation will require a huge capital, which alienates smaller businesses and might cost them their market share in the future.

Employment: While it still remains early to speculate on employment conditions with the adoption of Industry 4.0 globally, it is safe to say that workers will need to acquire different or an all-new set of skills. This may help employment rates go up but it will also alienate a big section of workers. Those workers whose work is perhaps repetitive will face a challenge in keeping up with the industry. Different forms of education must be introduced, but it still doesn't solve the problem for the elder segment of workers. This is an issue that might take longer to solve.

Privacy: This is not only the customer's concern, but also the producers. In such an interconnected industry, producers need to collect and analyse data. To the customer, this might look like a threat to his privacy. This is not only exclusive to consumers. Small or large companies who haven't shared their data in the past will have to work their way to a more transparent environment. Bridging the gap between the consumer and the producer will be a huge challenge for both parties.

Reliability and stability: It is a critical issue since there has to be uninterrupted communication needed for critical machine-to-machine communication (M2M), including need to maintain the integrity of production processes. There is a need to avoid any IT snags, as those would cause expensive production outages. The industrial know-how (contained also in the control files for the industrial automation gear) need to be protected.
In addition to the above challenges facing Industry 4.0, there is general reluctance to change by stakeholders. There is a lack of regulation (rather no regulation), standards and forms of certifications. Industry 4.0 is a new entity in manufacturing processes. Since there is no regulation, rules are not yet framed and legalised.

VII. THE FUTURE WORKFORCE

Companies have just begun to adopt additive manufacturing such as 3-D printing, which they use mostly to prototype and produce individual components. From 3D printed parts on commercial airplanes to those implanted in humans through innovative healthcare applications, 3D printing is incorporated in many areas of our lives. Now that 3D printing is a critical part of how businesses and manufacturers design and make products, it's changing the future of engineering. This technology allows for prototypes to be made quickly and economically.

With Industry 4.0, these additive-manufacturing methods will be widely used to produce small batches of customized products that offer construction advantages, such as complex, lightweight designs. Industry 4.0 has a lot to promise when it comes to revenues, investment, and technological advancements, but employment still remains one of the most mysterious aspects of the new industrial revolution. It's even harder to quantify or estimate the potential employment rates.What kind of new jobs will it introduce? What does a Smart Factory worker need to have to be able to compete in an ever changing environment such as this? Will such changes lay off many workers?

All of these are valid questions to the average worker. Industry 4.0 might be the peak of technological advancement in manufacturing, but it still sounds as if machines are taking over the industry. Consequently, it is important to further analyse this approach in order to be able to draw conclusions on the demographics of labour in the future. This will help workers of today prepare for a not-so-far future.

Given the nature of the industry, it will introduce new jobs in big data analytics, robot experts, and a huge portion of mechanical engineers.

Following are some of the important changes that will affect the demographics of employment:

Big-Data-Driven Quality Control: In engineering terms, quality control aims at reducing the inevitable variation between products. Quality Control depends to a large extent on statistical methods to show whether a specific feature of a product (such

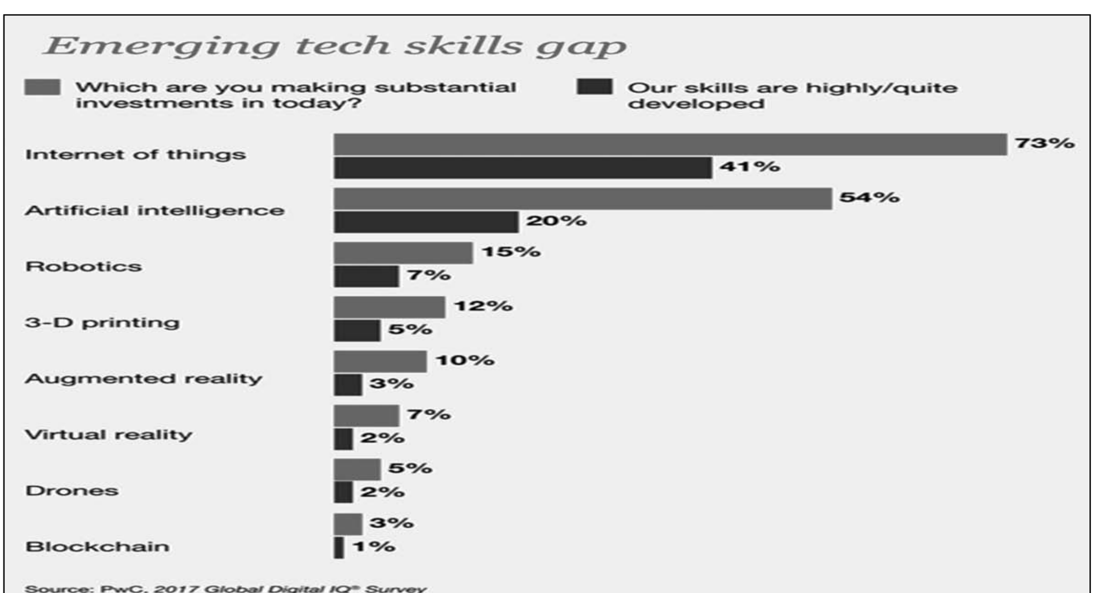


Figure 5. Technology Skills gap in different domains.

as size or weight) is changing in a way that can be considered a pattern. Of course such a process depends largely on collecting real-time or historical data regarding the product. However, since Industry 4.0 will rely on big data for that, the need for quality control workers will decrease. On the other side, the demand for big data scientists will increase.

Robot-Assisted Production: The entire basis of the new industry relies on the smart devices being able to interact with the surrounding environment. This means that workers who assist in production (such as packaging) will be laid off and be replaced with smart devices equipped with cameras, sensors, and actuators that are able to identify the product and then deliver the necessary changes for it. Consequently, the demand for such workers will drop and will be replaced with "robot coordinators".

Self-Driving Logistics Vehicles: One of the most important focuses of optimization is transportation. Engineers use linear programming methods (such as the Transportation Model) to utilize the use of transportation. However, with self-driven vehicles, and with the assistance of big data, so many drivers will be laid off. In addition, having self-driven vehicles allows for restriction-free working hours and higher utility.

Production Line Simulation: While the need for optimization for transportation declines, the need for industrial engineers (who typically work on optimization and simulation) to simulate productions lines will increase. Having the technology to simulate production lines before establishment will open up jobs for mechanical engineers specializing in the industrial field.

Predictive Maintenance: Having smart devices will allow manufacturers to predict failures. Smart machines will be able to also independently maintain themselves. Consequently, the number of traditional maintenance technicians will drop, and they'll be replaced with more technically informed ones.

Machines as a Service: The new industry will also allow manufactures to sell a machine as a service. This means that instead of selling the entire machine to the client, the machine will be set-up and maintained by the manufacturer while the client takes advantage of the services it provides. This will open up jobs in maintenance and will require an expansion in sales. This is also called leasing of equipment and is presently being used in many industry like Telecom, vehicles etc.

VIII. FINAL THOUGHTS

According to India Brand Equity report, under "make in India" initiative, the Govt of India aims to increase the share of manufacturing sector from 16% of the GDP to 25% of GDP By 2022.
It will help several companies:

- Through advanced analytics, improve connectivity for machine to machine and machine to product applications through IOT.
- Improve capacity of Organizations through Robotics and Automation using Virtual and Augmented Reality

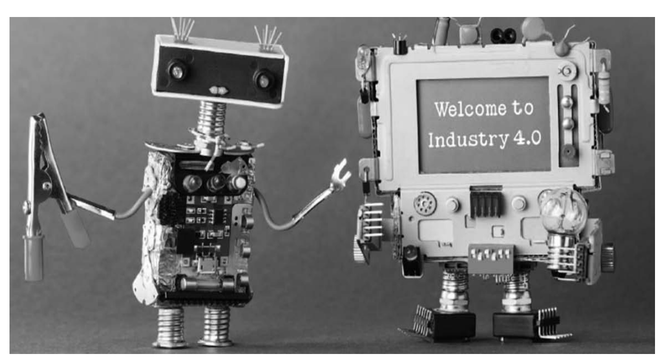
By applying Industry 4.0 to their business processes, companies can enhance operating profits by 40% at less than 10% of planned capex. Industry 4.0 will bring transformational change in manufacturing, equipment procurement, supply chain and all other verticals of the company performance.

Consumers are becoming more tech savvy and their lifestyles are changing. Consumers want to leverage IOT across domains to improve quality of life, increase productivity and automate simple tasks of everyday life. With increase in wireless connectivity at home, and availability of highspeed internet will help them to control their home devices and thus paving the way to Smart homes, and Social Networking.

Growing focus on reducing traffic blocking and accidents is driving the need for smart solutions among the automotive vertical. IOT helps the automotive industry to address the challenges pertaining to automotive safety and infrastructure.

Despite the challenges, there is little doubt that penetration of Industry 4.0 concepts in companies' manufacturing processes and supply chains will grow. Information flow, advanced technologies, and materials—in other words, the IT (Information Technologies) and OT (Operational technologies) that comprise Industry 4.0—make it possible to manufacture entirely new things in entirely new ways and revolutionize supply chains, production, and business models. Effective use of information can in turn impact key business objectives such as business growth and business operations, and transformation can be possible across the value chain and its various stakeholders. The path to realizationof Industry 4.0 involves a clear understanding of the ways in which the physical can inform the digital, and vice versa.

"The factory of the future will have only two employees, a man and a dog. The man will be there to feed the dog, and the dog will be there to keep the man from touching the computer /equipment"-- Warren G. Bennis



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Manjit Singh, FIETE was the President of Himachal Futuristic Communications Ltd. (HFCL), a pioneering Indian telecommunications company involved in the design, manufacturing, and deployment of wireless, optical, and PSTN equipment, as well as providing turnkey IT solutions to customers all over India. He was heading HFCL's technical operations and business development. Directed successful implementation of CDMA, GSM and WLL equipment including PDSN, billing, customer care, and SMS/VMS systems.

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Presently, he is running a small software export company for the development of software for different applications.

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