JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

# Visionary Concepts of Industry 4.0 for Manufacturing Firms: An Exploratory Study

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***Abstract :*** Manufacturing industries around the globe are being transformed by Industry 4.0 technologies and solutions in areas such as manufacturing, business operations, compliance, quality, and customer service. Although life sciences are typically behind other industries in terms of Industry 4.0 evolution, careful planning can result in significant gains. Further, regulators are adapting to the realities of Industry 4.0 and digital transformation, enhancing the potential. The benefits outlined above also make it possible to earn a healthy return on investment in addition to recruiting challenges and the need for increased resilience. As a result of Industry 4.0, factories, products, and supply chains could become more flexible, agile, and customer-focused. Moreover, it introduced a new integrated R&D framework for such purposes, focusing on the impact on inventory systems and optimization. Managing inventory efficiently and effectively is a challenge faced by all companies. The issue has been on the rise for some time, but no single solution fits all businesses. As a result, conventional methods of analyzing and optimizing inventory systems may have limitations, or a lack of knowledge about customers and suppliers may explain this. In the future, it is expected that new approaches and methods for optimizing inventory systems will be developed as Industry 4.0 advances.
***Key words:*** Industry 4.0, Digital Transformation, Inventory Systems, Optimization

## I. Introduction:

Industry 4.0s are revolutionizing how companies create, improve and distribute their products. These technologies include IoT, cloud computing, analytics and AI and machine synthesis. Advancements in technology allow manufacturers to use sensors, embedded software, and robotics to produce customized products at great efficiency. Combined with data from enterprise systems, this allows companies to make better decisions and create even higher quality productions. [1]

Effort is being made towards creating a basic level of legal contracting that provides more transparency and centralized power. Efforts are being made to concentrate scattered investment and construction management powers. Efforts include standardizing the new processes, enforcement of electronic forms of the construction process, and retraining for this process under law. [2]

### a. Features of Industry 4.0

Industry 4.0 is the process of integrating production with the latest tech and information. The product of mass customization is a manufactured product that takes into account the individual needs of a customer and can be tailored to fit the needs of the person buying it. One example of mass customization is customizing sneakers or furniture. [3]

With industry 4.0, you can create products of excellent quality and at a price comparable to that of mass-produced goods. Smart, digitally interconnected systems and production procedures serve as the technical basis for this idea. Industry 4.0 encompasses the entire life cycle of a product: from conception to development, manufacture, use, maintenance, and even recycling of the product when it's no longer needed. To better illustrate this concept, the development of industry 4.0 is shown in figure 1.1. [3]

Industrial revolutions were the three major industries in the past. The first one was the invention of steam machines, making a significant level of mechanization whereas the second one involved electricity and assembly lines. The 3rd Industrial Revolution connected IT and technology to the production process through automation. [3]

The 4th innovation level, Cyberphysical Systems, uses digitalization and IoT concepts. The first steam powered machines took a long time to invent. There was a 100 year difference between the introduction of the 1.0 and 2.0 versions of this technology. Level 3.0 was introduced after 70 years, and now we are expecting the development of 4.0 to happen in the next 20-30 years from now, it has to be noted that in that time span there may be even faster forms of this technology introduced before then if they were invented by then. [3]

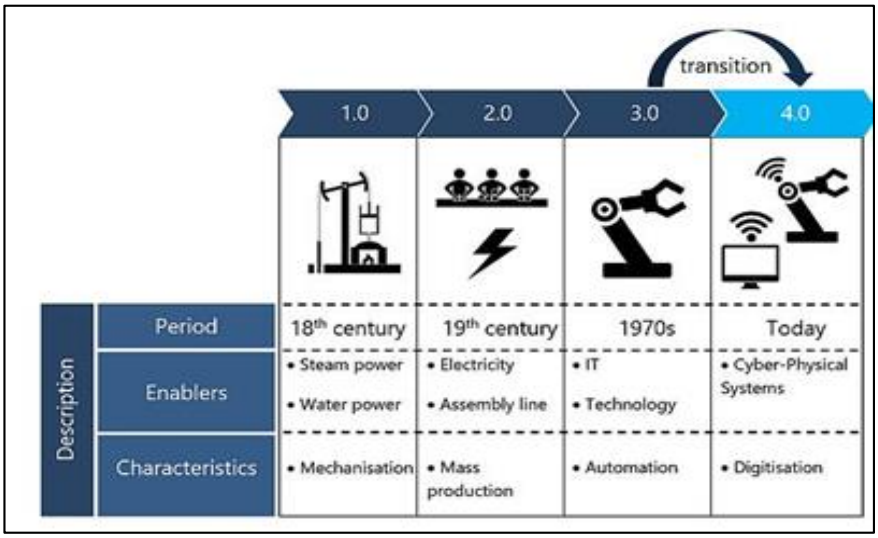


*Figure 1.1Industry 4.0 Concepts*

Industry 4.0 was designed by the German government to maintain Germany's industrial competitiveness on the global market. The main features of Industry 4.0 are: [3]

- Interoperability: Technologies that allow humans and smart factories to communicate.
- Virtualisation: Engineers can exhibit an intelligent factory by linking solar data with virtual models.
- Decentralisation: With decentralisation, cyber-physical systems can produce locally and make their own decisions.
- Real-Time Capability: the capability to collect and data and provide the derived insights immediately.
- Modularity: flexible adaptation of smart factories to changing requirements by replacing or expanding individual modules. [3]

**II. Benefits and Challenges of Industry 4.0**

Industry 4.0 is described as a revolutionary paradigm in which three transitions occur: industrial production and construction, cyber-physical system, and digital technologies. BIM, CDE, cloud-based systems engineering, AR/VR, big data and analytics, blockchain, and laser scanners are all instances of emerging innovations. Robotics and automation, sensors, the internet of things, industrial manufacturing, off-site and on-site construction, employees using wearable sensors, and devices fitted with sensors all fall into the category of cyber-physical systems. As a result, it's crucial to comprehend the developments that make this transition possible. Whereas the current study library addresses several Construction 4.0 technologies, this work aims to focus on eight of the most commonly cited Construction 4.0 technologies. Below is a short overview of each of these technologies: [4]

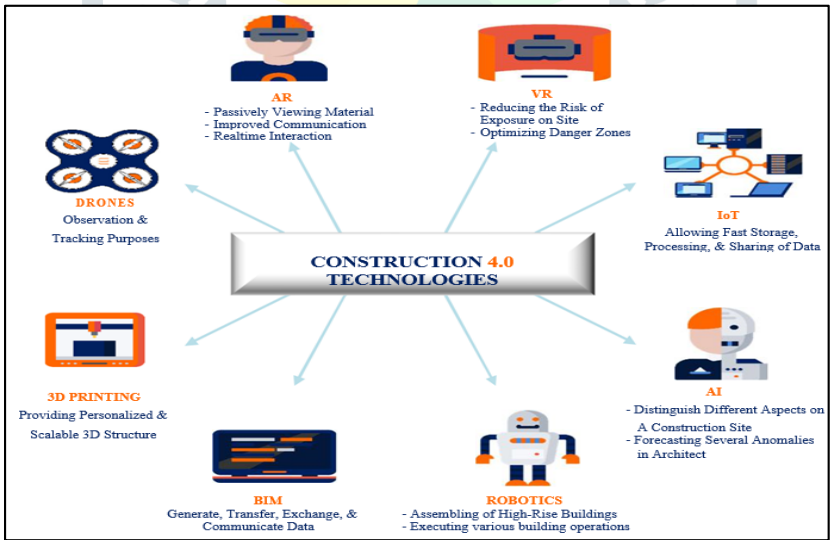


*Figure 1.2 Industry 4.0 Technologies*

- Drones: Drones are mostly used in the construction industry for observation and tracking purposes during survey work, construction, and facilities operations. In the past, they were primarily used for military purposes. Using drones in building and other industries have risen steadily over the years. [4]
- Augmented Reality is a data platform and publishing program that enables users to passively see viewed material, remain engaged and communicate with published material, and interact in real-time with people from different areas. AR is defined as a combination of reality and virtual reality. AR is growing in popularity in the construction sector, with a range of use-

cases been studied and tested during the project lifecycle, including supporting AR-enabled manufacturing process and facilitating remote expert systems. [4]

- VR: is a step further than AR on the spectrum of virtuality. VR creates a virtual and an immersive experience for the user through headsets with 360-degree visions, allowing the user to experience a completely different environment. Since 1990, it has experienced remarkable growth, undergone development, and been applied in areas such as education and training. When using VR in training related to the construction industry, it reduces the risks people may be exposed to, optimizes procedures, and makes it possible to identify danger zones. [5]
- 3D Printing: The method of making a dynamic, physical 3D structure from a CAD model is known as 3D printing or additive manufacturing. 3D printing has been the focus of 25 years of research and development, and it is now used in several fields, including aerospace, vehicles, and medicine. The construction industry is still looking at 3D printing, but mostly for small to medium-sized projects right now. These technologies have recently ignited attention in the Construction 4.0 sector, particularly with cement, lending to its potential to substitute human workers with automated manufacturing, enabling substantial saving of time as well as personalized and scalable construction manufacturing The final result is heavily influenced by the printing quality, material behavior, speed, and printing duration between layers . [5]
- BIM: is a computer program that allows all stakeholders in the construction process to generate, transfer, exchange, and communicate data. BIM has been critical in the building industry's digitalization. Overall, BIM – specifically 5D planning and budget integration – is supposed to result in substantial cost savings across the entire construction value chain. In other words, BIM can enhance operating processes over the lifespan of a construction project. Today, Building Information Modeling is considered to be the central technology for the digitization of the construction manufacturing environment.
- Robotics: This technology is widely used in the construction industry, particularly in the assembling of high-rise buildings. For example, the SMART machine built by SHIMIZU in Japan was also used to create a 30-story office tower. Furthermore, robots can execute various building operations like painting, brick overlaying, and earthwork. [5]
- AI: is a concept that refers to a computer that mimics human cognition. Throughout the construction industry, 4.0 AI can be used in adaptive vision systems to distinguish different aspects on a construction site, as well as voice and recognize patter to track the progress of construction workers in full detail. It's still being analyzed to see how it can forecast several anomalies involved in building architecture, construction, and service. Furthermore, intelligent manufacturing is a viable technique. [6]
- IoT: Using built-in sensors and wireless technology, the Internet of Things allows for the fast storage, processing, and sharing of data. It's generally acknowledged as one of the most critical fields of future technology, and it's gaining a lot of interest from sectors. In the context of construction 4.0, the Internet of Things is being used to incorporate goods. [6]

Many of these advancements in technology today present new opportunities for businesses who wish to enhance their competition, operations quality, project delivery punctuality, as well as new services delivered to customers. [7]

Also, several of these technologies, such as BIM, sensors, and the Internet of things, have proved to be useful in accomplishing the objectives for a prosperous future. Along with the enormous potential and promise of sustainable decision-making in the field of construction technology. In other words, investing in new technology contributes to improved efficiency, and that's what companies like construction are looking for. [7]

**III. Benefits of Industry 4.0 to Manufacturing firms**

- **Reduced machine downtime and improved productivity:** With Industry 4.0, you can achieve more with fewer resources. In other words, you can increase throughput while allocating resources more efficiently and cost-effectively. As a result of deeper levels of integration, improved machine monitoring, and automated/semiautomated decision making, your production lines will also experience less downtime. As your facility moves toward becoming a smart factory, OEE (Overall Equipment Effectiveness) will also improve.

- **Efficiency has been improved:** A number of aspects of your production line will become more efficient as a result of Industry 4.0-related technologies. A few examples are below - less machine downtime as well as the ability to produce more and faster products. In addition to batch changeovers, automatic track and trace processes, and automated reporting, new product introductions (NPIs) and business decisions become more efficient as well.

- **Management and security of the supply chain are optimized:** By integrating Industry 4.0 technologies, processes, and systems, your supply chain will be better connected, enabling real-time monitoring with enhanced communication and

collaboration. By having this advanced knowledge, you can take steps to mitigate bottlenecks and other supply chain problems before they have an impact on production output. As a result, your supply chain will be more resilient and agile, improving your ability to respond to changes in market conditions and customer demands.

- **Digital twins optimize the product, production line, and factory lifecycles:** It collects data in the physical world to create a digital replica that updates in real time. It can be a twin of a product, a production line in your facility, or even your entire factory. This digital twin allows you to optimize performance and efficiency and test different scenarios without affecting real-world output. You can also identify areas for improvement and innovation.

- **Empowered People:** Your people will be able to take data-driven decisions with the help of Industry 4.0 technologies. With automation technologies and advanced workflows, you can eliminate the need for your people to work on repetitive tasks. Your team can concentrate on value-added activities instead.

- **Collaboration and knowledge sharing:** In traditional manufacturing plants, individual facilities as well as individual machines within a facility are silos, resulting in little collaboration and knowledge sharing. With industry 4.0 technologies, your production lines, business processes, and departments can communicate regardless of their location, time zone, platform, or any other circumstance. For example, a sensor on a machine in one plant can be used to share knowledge across your company. The best part is that this can be done automatically, i.e., machine-to-machine and system-to-system, without any human intervention. In other words, data from one sensor can instantly improve multiple production lines located anywhere.

- **Agility and flexibility:** Among the benefits of Industry 4.0 are enhanced flexibility and agility, such as the ease of scalability and flexibility. As a result, it is easier to introduce new products to the production line as well as to create one-off manufacturing runs, high-mix manufacturing, and so on.

- **Facilitates compliance:** Pharmaceutical and medical device manufacturers do not have to manually comply with regulations. By automating compliance, such as track and trace, quality inspections, serialization, data logging, and more, Industry 4.0 technologies make it possible.

- **Quality-improved products:** With Industry 4.0, quality functions can be moved from the inspection room to the production line, resulting in in-line inspections that are automated in real time. As a result, an inspection process evolves from a go/no-go approach to one that is continuously measuring and analyzing to improve processes and identify quality issues so they can be corrected before they become a failure. Additionally, automation will reduce human error in quality functions and automate data collection, transmission, and storage.

- **Providing better customer service:** With Industry 4.0, you can also improve your service to customers and enhance the customer experience. For instance, you can quickly resolve problems with automated track and trace capabilities. In addition, you will have fewer issues with product availability, product quality will improve, and you can offer customers more choice.

- **Personalized Products:** As a result of the benefits they offer to patients, the medical device and pharmaceutical industries are moving towards personalized products. For production facilities, this means mass customization and increasingly smaller batch sizes. Life sciences manufacturers can personalize products in a high-speed mass production environment using Industry 4.0 solutions.

- **Cost-savings:** Smart factory certification doesn't happen overnight, and it won't happen on its own. You need to invest, so there are upfront costs. However, Industry 4.0 technologies will reduce the cost of manufacturing at your facility.

- **Creating opportunities for innovation:** You will gain a better understanding of the manufacturing process, supply chains, distribution chains, business performance, and even the products you produce with Industry 4.0 technologies. As a result, companies can innovate, whether they are changing business processes, developing new products, optimizing supply chains, improving OEE, etc.

- **Decision-Making Improved:** Machines and systems need to become more integrated in order to be able to capture and use data, which is a key aspect of Industry 4.0 and smart manufacturing. A true data-driven decision-making process can be achieved in medical device and pharmaceutical manufacturing facilities as a result. Machines can also make data-driven decisions, further enhancing automation.

- **Increased revenue:** Several of the above points can result in higher revenue for your production facility. In order to meet an increase in demand or compete for a new contract, you might be able to add a new shift with minimal staffing costs if you automate your production line and implement other Industry 4.0 technologies.

**4. Conclusion and Future Directions:**

As a result, Industry 4.0 technologies and solutions are transforming manufacturing industries across the globe in areas such as manufacturing, business operations, compliance, quality, and customer experience. Life sciences are generally behind other industries in terms of Industry 4.0 evolution, but careful planning can result in significant gains. Additionally, regulators are adjusting to the realities of digital transformation and Industry 4.0, enhancing the potential even further. Besides recruitment

challenges and the need to increase resilience, other drivers are also accelerating the push towards Industry 4.0 solutions. The benefits outlined above make it possible to earn a healthy return on investment as well.

Industry 4.0 has the potential to revolutionize factories, products and supply chains, making them more agile, flexible and customer-focused. This chapter provided an overview of Industry 4.0 and touching upon its key features, showing how they can benefit businesses in terms of manufacturing systems and services. To further elaborate, it examined the impact on inventory systems and optimization as well as introducing a new integrative R&D framework for such purposes. The challenge of managing inventory efficiently and effectively is one that all businesses and companies face. It has been an ongoing issue for some time now, but there is no single answer that fits each and every business. This may be due to the restrictions of conventional methods of modelling and optimizing inventory systems, or simply from a lack of knowledge concerning customers and suppliers. As Industry 4.0 continues to advance, however, it is expected that new advances in approaches and methods for inventory system optimization will be forthcoming.

Cloud computing, Blockchain, analytics of big data, IoT, and 6G networks are among the technologies enabling industry 5.0, which we want to study and implement in future work,

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