What is the Industry 4.0 and can it be a solution for increasing Effectivity and Efficiency of Engineering Organizations

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***Abstract*— In this scholarly review paper, the authors examine the concept of Industry 4.0 and its potential to enhance the efficacy and efficiency of engineering organizations in a wide range of industries, including the automotive, FMCG, and medical sectors. Dubbed the Fourth Industrial Revolution, Industry 4.0 encompasses the integration of innovative technologies such as the Internet of Things, artificial intelligence, and big data into industrial processes. The implementation of Industry 4.0 holds the promise of significant organizational benefits, including heightened productivity, reduced costs, and improved decision-making abilities.**

Keywords: Digital transformation, Smart factories, Predictive maintenance, industry 4.0 technologies, Product lifecycle management, Supply chain management.

I. Introduction to industry 4.0

Industry 4.0 refers to the fourth industrial revolution and it is about using modernized systems to revolutionize the way we make things. It blends physical and digital technology to make production faster, more accurate and efficient. Smart factories are being built with machines that can talk to each other, thanks to the Internet of Things (IoT), making it possible to collect and analyze data in real-time. This allows for production to be optimized even further with the help of advanced analytics and AI. On top of all that, Industry 4.0 also opens up opportunities to create new products and services, as well as being able to adjust to market changes quickly[3].

Industry 4.0 is a term that refers to the present trend in production of employing technology to automate operations and exchange data. It is the fourth great industrial revolution, following the steam engine, electricity, and computers. This emerging technology trend employs cyber-physical systems, the Internet of Things, cloud computing, and cognitive computing to accelerate and improve manufacturing. It integrates physical and digital technologies to improve efficiency and save expenses. This can benefit engineering companies by increasing their effectiveness and efficiency. Automation and data interchange can also increase manufacturing accuracy and speed while making better use of resources. Engineers can make better judgments using cognitive computing because they can access real-time data and insights. Industry 4.0 has the ability to make engineering safer by eliminating human error and preventing possible risks. Engineers may also access up-to-date information from anywhere in the globe thanks to cloud computing[4].

A. Evolution of Industrial Evolution

Different industrial revolutions evolve in the following manner [1].

1) The First Industrial Revolution :

The First Industrial Revolution began at the end of the 18th century (1760-1840), with the introduction of machines into the manufacturing process. During this revolution, manual labor is improved, and the industry attempts to create comfort through the use of steam-powered engines. It greatly aided agriculture and caused significant changes in the textile industry.

2) The Second Industrial Revolution :

It occurred between 1870 and 1914, with the introduction of railroads and telegraphs into industries. The prime objective of this revolution was to bring about mass production and innovation in chemistry and related disciplines.

3) The Third Industrial Revolution :

Between 1950 and 1970, the integration of digital technologies into manufacturing systems marked the Third Industrial Revolution. This revolution aided in the transition

from analog to mechanical systems. Communication, computer, and information technology are advancing rapidly (IT). It introduced a new level of manufacturing system automation by introducing flexible and customized production using various manufacturing technologies that operate independently with the help of a computer.

4) The Fourth Industrial Revolution :

It is expected to begin in 2020 and is designed to meet the industry's future needs. This industrial revolution is heavily reliant on disruptive innovations such as three-dimensional (3D) printing, AI, IoT, and robotics. It has the potential to disrupt many business models, industries, and the entire scenario. It refers to the evolution of manufacturing processes and supply chain production. Industry 4.0 refers to a new production style that efficiently and effectively uses new manufacturing techniques through the combination of intelligent manufacturing machines. It establishes a smart factory in which customization is carried out efficiently.

B. Overview of Engineering organization

Engineering organizations play a crucial role in the advancement and maintenance of the products, systems, and services that form the backbone of modern society. These organizations consist of a multidisciplinary team of engineers, scientists, and professionals who work in tandem to achieve common goals. At the helm of the organization, there is typically a leader or executive who sets objectives and oversees operations, while departments such as engineering, research and development, manufacturing, and marketing exist beneath the head, each staffed with experts in their respective fields. The primary focus of engineering organizations is the creation of new products and services, as well as the improvement of existing ones, and they also aim to stay ahead of the curve in regards to emerging technologies and processes, such as artificial intelligence and robotics. The organizations are also responsible for ensuring the maintenance and repair of current products and services, with a paramount emphasis on safety, quality, and efficiency. To this end, various tools and techniques are utilized. Understanding the operations and goals of engineering organizations is of great significance in the academic community, as it provides insights into the impact they have on modern society[2].

II. Prerequisites if implementing Industry 4.0

The implementation of Industry 4.0 technologies in engineering organizations offers a vast variety of benefits. Not only can it positively impact the efficiency of engineering organizations but it assists in the gradual attainment of the sustainable product concept. The Smart factory, which works on the principles of Industry 4.0, consists of various closely integrated systems which can adjust their operations in response to market variations, consequently optimizing the overall production process. However, the application of Industry 4.0 to engineering organizations has several prerequisites and associated challenges that must be dealt with in order to achieve the results.

A. Financial Resources :

The implementation of Industry 4.0 in the engineering organization requires sufficient financial resources to be invested in the technological requirements. Making use of advanced technologies including IoT, CPS, Cloud Computing, and RFID, appropriate capital is required in fulfilling the hardware and software needs to fill the technology gap. Moreover, investment is also a requirement for the training of the staff to handle the associated complexities of Industry 4.0 technology.

B. Access to Technology :

The concept of a Smart Factory makes use of various sensors, controllers, network infrastructure, data handling servers, and various other smart devices for automation and robotization of the manufacturing processes.

C. Flexible Production System :

Industry 4.0 utilizes real-time market data based on which it can react to changing demand and modify the production process. This flexibility in the production process is only possible with the employment of advanced, automatic, and fast interchangeable tooling.

D. Skilled and Qualified Professional :

Qualified personnel having the capability to operate and manage industry 4.0 tools is of utmost importance. Furthermore, implementing this concept requires competent and skilled staff, which are sufficiently flexible and innovative. This consists not only of training staff and improving their knowledge but also encouraging teams to become individual initiators of change.

E. Vertical and Horizontal Integration :

Within the engineering organization, the departments should be collaborative and a strong culture of cooperation must exist. Furthermore, horizontal integration is required between the engineering organization and various external elements of the supply chain.

F. Real-Time Data and Storage Capability :

Since all major decisions are being made basis on the available real-time data, its collection, storage, analysis, and security is a critical aspect of Industry 4.0. Data management is a key challenge for engineering organizations in implementing Industry 4.0 since it requires not only handling the enormous amount of data, but also the expertise to analyze it. For Industry 4.0, focus is needed on crucial information which will be used within the production process that will allow the system to take appropriate decisions.

III. Application of industry 4.0

A. Industry 4.0 in FMCG :

Industry 4.0 has gained a lot of attention and popularity in the electronics and machinery industries, but it also has an impact on the food industry and other connected industries. Increasing population has a significant impact and higher requirements in terms of effectiveness and food safety which is amplified by globalization. In addition to the ongoing rise in quantitative demand, quality standards are

also under greater pressure and significant variation due to the changing product mix, rising energy costs, and environmental burdens. For businesses, where the benefits of digitalization are a major help, adapting to these new problems may be the best - or indeed the only - option.
Generally, the food industry is characterized by persistent, significantly shifting trends, particularly in terms of product mix and processing needs - among others, as a result of the rising popularity of healthy and clean eating. Along with changing customer demand and requirements, there is also tremendous pressure from the retail chain, which claims that quality, selection, and food safety are all improving while prices are continuously going down. Digitization and Industry 4.0 can provide these market players with an efficient and long-term support system or solution if they adhere to all of these needs.

Some smart factory advancements, such as automation or robotization, have been used for a while in specific sectors of the food industry, such as pasta production or dairy processing. However, there are still some industries, such as the meat industry or the bakery industry, where the potential is constrained by the complexity of the processes or the high demand for human labor. Higher productivity, lower scrap rates, and an overall improvement in quality were the results of these actions in all areas where automation can be adopted or improved. Given that it is one of the most priceless items for humanity going forward in terms of both practical and moral considerations. Additionally, further positive aspects on the software side of this situation include data collection, analysis, and structuring, decision-making support activities, and authoritative reporting opportunities helps increase further the competitiveness of companies.
There are fewer other sectors where it would be more crucial to trace products and identify the entire supply chain, i.e., in the event of a product recall. It is more significant in today's globalized world. RFID, bar-code reading, block chain technology, and sensors all play a significant role in these aspirations and are specifically regarded as fundamental technologies for digitized food sector processes.

B. Industry 4.0 in Medical Industry :

Industry 4.0 which is the idea of accomplishing faster advancement in assembling with expanded productivity in the supply chain. In the clinical field, Industry 4.0 appears to provide broad applications for the formation of tweaked inserts, instruments, and gadgets. This revolution provides a superior approach to utilizing data, manufacturing, and services to improve quality of life. Accordingly, it gives new opportunities in manufacturing and extends the boundary of innovation through the application of the Internet of Things and the Internet of Services.

The potential for the use of robotics and automation is one of the most exciting aspects of Industry 4.0 in the medical industry. The integration of automation technology within the medical sector holds the potential to disrupt traditional methods and elevate the patient experience. Automated processes, such as medication delivery, can be streamlined and administrative tasks, such as paperwork, can be reduced. Robotics can support diagnostic procedures, patient monitoring, and even complicated medical interventions, such as surgeries. The utilization of artificial intelligence (AI) is a crucial aspect of Industry 4.0 in healthcare. AI can analyze massive amounts of data to reveal patterns and trends, thereby improving the precision of diagnoses and treatments. Furthermore, AI can automate functions like patient record tracking and appointment scheduling. Ultimately, Industry 4.0 in the medical sector has the capability to enhance the overall patient experience

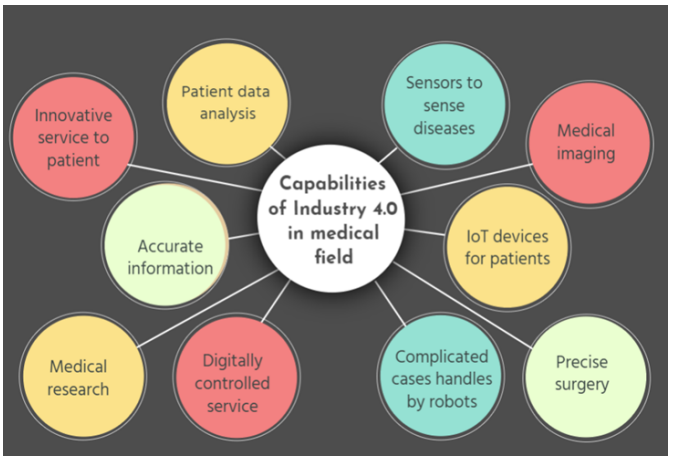

Fig.1 Different capabilities of Industry 4.0 in the medical fields

Industry 4.0 could give exciting capacities and new open doors for patient consideration. It individualizes items with the precise manufacturing of patient explicit devices which makes a high-quality outcome. It additionally emphatically influences the emergency clinic board system with the assistance of creative technologies. In medicine, this revolution will turn into another reality to make inventive ideas and remain competitive. It effectively changes the entire course of the medical field through industry 4.0 and offers inventive support to patients by investigating the information of the patient with the help of sensors and IoT. It gives exact data utilizing forthcoming medical imaging methods and carries out the exact procedure. It serves to deal with various convoluted cases with the assistance of carefully controlled support of the patient without any problem. This revolution will promptly attempt new examinations and improvements in the medical field. One of the brilliant abilities of this is the reusing of medical waste in the clinic which saves our current circumstances. The new capacities are all around taken by Industry 4.0 in medical and assist with making great support of the patients and specialists [6][7].

C. Industry 4.0 in the Automotive Industry :

The concept of Industry 4.0 is also known as smart manufacturing in the Automotive industry. a system that is flexible and automatically adapts to the production of different products and any other change in Conditions. This helps to improve flexibility, productivity, and product quality, and manufacture customized products at a large scale with better consumption of resources. The CPS (Cyber Physical System) communicates over IoT (Internet of Things) and the IoS (Internet of service), which enables a “smart factory,” built on the idea of a decentralized production system, in which “human beings, machines, and

resources communicate with each other as naturally as in a social network". "Smart factory" is considered an essential feature of Industry 4.0, in which products go through the processes independently, yet cost-efficient as well as highly flexible.

Industry 4.0 also involves technologies that are embedded in products (also known as smart products). These technologies comprise smart components which support digital capabilities and services during the offering of a product. The sensors embedded in such products allow connecting with other products in the network. Sensors and RFID technologies provide monitoring capabilities in products, which will enable customers to know about the condition of a product. The use of artificial intelligence helps products to optimize autonomously. Smart products can help to provide feedback with data that can be useful for developing new products. Therefore, some researchers also consider the development of smart products to be another essential objective of Industry 4.0 technology.

Industry 4.0 can also significantly influence the production environment. It can enable simultaneous planning of production plans and dynamic self-optimization, Whereas the current forecast focuses on production planning-based systems. Thus, Industry 4.0 is better able to enhance the execution of operations. One of the best examples of implementing Industry 4.0 in the automobile industry can be seen in the Toyota Production System. The system is embedded with the latest technologies and intelligent algorithms in synchronization with Industry 4.0 [9].

IV. Future perspective of industry 4.0 in engineering organization

A. Data Collection

For the majority of industrial organizations, real-time data collection is necessary to keep up with the Industry 4.0 era. These problems may have solutions owing to IoT and CPS. The following may be done in the future for real-time data collection in industrial systems:

1) IoT-enabled data collection:

Typical IoT components can be embedded into a variety of production resources, including RFID and barcoding. So that real-time production data may be recorded and gathered, they are transformed into smart manufacturing objects (SMOs) that can intelligently interact and communicate with one another.

2) Smart sensors:

Smart sensors may now integrate multifunctional capabilities to gather real-time data on temperature, force, pressure, and humidity thanks to the rapid evolution of cutting-edge technologies. These sensors are connected to different SMOs so that production lines, working stations, and manufacturing activities can be integrated with physical operational and information flows.

3) CPS -Based smart machines:

Utilizing CPS technology, machines will eventually be transformed into smart objects. Real-time data from smart machines can be sent to a central cloud-based "manager" who can use visualization to keep track of their conditions.

B. Visualization

Manufacturing organizations are currently having trouble exhibiting and perceiving a variety of manufacturing services. In Industry 4.0, information visibility is crucial for making accurate decisions. Implementing factory virtualization and visualization presents a number of difficulties. First, to guarantee production quality and safety, manufacturing objects should be visualized in real time. To fill these gaps, future research should emphasize the following aspects.

1) AR-enabled real- time visibility:

Manufacturing can benefit from real-time machine visibility thanks to the application of AR technologies.

2) Cyber virtualization modeling:

The cyber virtualization technique models various physical manufacturing resources so that their potential and status can be reflected on a cloud platform that will be shared across an alliance.

C. Decision -making

Decision-making in Industry 4.0's smart manufacturing systems requires knowledge and information that can be gleaned from vast production data sets. In a recent survey, 55% of the participants believed that upper levels of their businesses did not value decision-making. Several issues need to be resolved in light of the huge data from manufacturing locations. First, when using vast volumes of data, decision models take a while to arrive at a solution. Different objectives are used for specific things, such as improving production planning and scheduling. When making decisions, nevertheless, exact data input is insufficient. Second, Industry 4.0 decision-making is always focused on maximizing the usage of manufacturing services and equipment through resource sharing. Future decision-making should focus on two directions:

1) Decision-making models are driven by big data analysis:

These models can extract valuable knowledge and information from vast production data sets to aid in the formulation of certain decisions. These models, where big data analyses are packaged as services, can include cutting-edge technology or algorithms, such deep machine learning. Cloud manufacturing may turn different production resources into services with the use of IoT and cloud technology, enabling end users to request services on demand and pay for them conveniently as they are used. Additionally, the incorporation of CPS into cloud manufacturing enables production operations to be monitored and run remotely. As a result, virtual services and physical equipment are used to assist manufacturing processes and decision-making. [2] Even though industrial methods have dealt with several I4.0-related issues throughout time, there are still numerous areas for further investigation given that the I4.0 concept and its key indicators are still being measured and studied. In terms of

horizontal integration, the future scope is related to integrating various IT systems used at various stages of manufacturing and business planning processes within a company (for example, inbound logistics, production, outbound logistics, and marketing) as well as between several different companies (value networks). In terms of vertical integration, the future scope relates to the integration of various IT systems at various levels of hierarchy (for example, actuator and sensor level, manufacturing and execution level, production management level, and corporate planning levels) in order to deliver an end-to-end solution.

2) End-to-End Digital Integration:

Integration during the engineering process to incorporate client requirements while integrating the digital and real worlds throughout the whole value chain of a product and across several companies. Equally important for businesses to concentrate on are standardization, reference architecture, managing complex systems, delivering, safety and security, work organization and design, training, regulatory framework, resource productivity, and efficiency. In particular, add to and restructure scales that cross-reference the degree of implementation, present state, and level of use of I4.0 components (CPS, IoT, Cloud Computing, Data, etc.). The risks from IT are affecting the industrial manufacturing process, therefore we need to mitigate new possible manufacturing industrial risks, not just in all systems-related risks, but also in manufacturing industrial risks in human capital.

V. CAN IT BE A SOLUTION FOR INCREASING EFFECTIVITY AND EFFICIENCY OF ENGINEERING ORGANIZATION?

Implementation of I4 technologies is changing the way of working of people. I4 technologies involve bringing a lot of changes to an organization. resistance to change is a prominent barrier to the implementation of I4 technologies. Therefore, a firm should be open and ready for change while working in the era of I4. In this regard, the role of leadership and management becomes very crucial. Top management needs to take a proactive approach to the implementation of I4 technologies. I4 is "a revolution in manufacturing," which focuses on collaboration between manufacturing and emerging technologies to maximize output with minimum use of resources. The implementation of I4 considers the exchange of information and integration of the supply chain, thus synchronizing operations with suppliers, which reduces the delivery time and distortion of information. From the operational point, I4 technologies can help to reduce material costs, processing times, and set-up times, which can increase the overall productivity of the processes. Implementing I4 technologies also helps to stabilize operations thereby providing improved working conditions and increasing the safety of workers. Some of the other benefits of implementing I4 technologies include Enhanced sharing of information, increased collaboration in operations, superior competitive advantage, increase in the end-to-end transparency and visibility of operations, optimization of manufacturing systems in terms of consumption of energy and resources, and reduction in operational and production costs[8].

In the following the so-called „smart" designs and solutions are listed related to the online fulfillment process – the analysis was made by validation of all the relevant and significant market players to get a comprehensive picture of these days' practices.

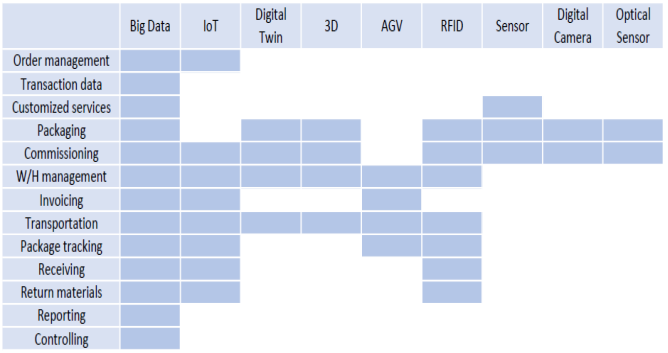

Fig.2 Intelligent logistics solution in the online fulfillment process

The purpose of this matrix and the analysis is to support the 'followers' on the market and point out the right directions for further bench-marking activities. Of course, opportunities and developments are continuous and changing dynamically in the market. This is why it is not only a possibility but rather a necessity to follow these trends and monitor them easily[5].

A. Case study of BOSCH

With the goal of becoming a top provider of connectivity solutions for the Internet of Things, Bosch (Germany) has a long-term strategy to transition into Industry 4.0 [11]. The financial gains that the Bosch Automotive Diesel System firm saw as a result of applying Industry 4.0 to streamline its production. Bosch was suffering from production failures and losses, which prompted them to look for a technique to spot production bottlenecks and avoid them. Bosch connected its machines to track the complete manufacturing process at the center of its plant since merging IoT and big data is a significant component of the digital transformation the company is going through. They were able to anticipate production failures by employing data analytics to evaluate the data in real time, which allowed them to stop losses before they even began. Throughput increased by more than 10%, while customer satisfaction and delivery times were consistently improved. The use of an AI-powered data solution finally made it possible to make data-driven decisions, which led to optimized output. Automotive manufacturers may solve quality and throughput losses in production and assembly processes by utilizing Industry 4.0 technologies. For instance, problems with dashboard assembly, paint thickness, coating, surface quality, interiors, and more can all be avoided. By doing this, they gain long-term commercial advantages that result in higher ROI.
The integration of electrical and computer systems into engines and cars has significantly deteriorated with the manufacturing industry's revolutions, while fuel and motion

systems have improved in quality and efficiency in many areas, from fuel consumption to vehicle design and cost. The automotive industry is undergoing rapid change, much like all other industries. The industry 4.0 process in the automotive sector is being quickly influenced and sparked by intelligent Internet-connected gadgets, robot technologies, and high-tech computers. Automakers, who are more efficient, high-quality, and economically competitive, are always coming up with new ideas to stay ahead of the digital transition. Information technology is being transferred under the term "Industry 4.0" in order to advance automation systems further following robot technologies in the automotive industry. The effects of industry 4.0 have proven positive for the automobile sector. Just automating and improving productivity is a step forward. Industry 4.0 has the ability to transform smart manufacturing operations management in a comprehensive and all-encompassing way, revolutionizing the vehicle manufacturing sector.

B. Statistical Information

Researchers and experts agree that Industry 4.0 influences various aspects of our world and has suggestions for the vast majority of business fields, including Healthcare, quite possibly the most grounded area these days. In most developed nations, Healthcare represents over 10% of the Gross domestic product, while worldwide Healthcare spending is supposed to reach roughly $9 trillion by 2021 [12]. Appropriate information plays an important role in the healthcare 4.0 solution. As Healthcare is one of the areas that produce the greatest proportion of data, such as biomedical data, Electronic Prosperity Records (EHR), and genuine records, researchers and professionals see the importance of the Healthcare Data Assessment to drive the affirmation of affiliation benefits. As indicated by a Complete Research Report by the IT patterns research organization Statistical surveying Future, the worldwide market will accomplish a build development pace of 18.2% with a pay of 81.3 billion USD constantly 2030 [13].

VI. CONCLUSION

In conclusion, Industry 4.0 presents a great opportunity for engineering organizations to improve their operations and performance. The utilization of cutting-edge technologies such as IoT and AI can result in real-time monitoring and control, increased accuracy, reduced downtime, and increased productivity. Automation of routine tasks and integration of AR can supply engineers with current information, leading to more informed decision-making. Furthermore, Industry 4.0 can result in cost savings, positively impacting the bottom line and assisting in maintaining a competitive advantage in the market. Adopting Industry 4.0 principles can greatly benefit engineering organizations and enhance their overall efficiency, effectiveness, and competitiveness. All in all, Industry 4.0 is a transformative approach that has the potential to revolutionize the engineering sector and drive growth for years to come.

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