Advances in Science, Technology & Innovation
IEREK Interdisciplinary Series for Sustainable Development

Anand Nayyar · Akshi Kumar *Editors*

A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development

Springer

Advances in Science, Technology & Innovation

IEREK Interdisciplinary Series for Sustainable Development

Advances in Science, Technology & Innovation (ASTI) is a series of peer-reviewed books based on the best studies on emerging research that redefines existing disciplinary boundaries in science, technology and innovation (STI) in order to develop integrated concepts for sustainable development. The series is mainly based on the best research papers from various IEREK and other international conferences, and is intended to promote the creation and development of viable solutions for a sustainable future and a positive societal transformation with the help of integrated and innovative science-based approaches. Offering interdisciplinary coverage, the series presents innovative approaches and highlights how they can best support both the economic and sustainable development for the welfare of all societies. In particular, the series includes conceptual and empirical contributions from different interrelated fields of science, technology and innovation that focus on providing practical solutions to ensure food, water and energy security. It also presents new case studies offering concrete examples of how to resolve sustainable urbanization and environmental issues. The series is addressed to professionals in research and teaching, consultancies and industry, and government and international organizations. Published in collaboration with IEREK, the ASTI series will acquaint readers with essential new studies in STI for sustainable development.

More information about this series at http://www.springer.com/series/15883

Anand Nayyar • Akshi Kumar
Editors

A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development

Springer

Editors
Anand Nayyar
Graduate School
Duy Tan University
Da Nang, Vietnam

Akshi Kumar
Department of Computer Science and Engineering
Delhi Technological University
New Delhi, India

ISSN 2522-8714 ISSN 2522-8722 (electronic)
Advances in Science, Technology & Innovation
IEREK Interdisciplinary Series for Sustainable Development
ISBN 978-3-030-14543-9 ISBN 978-3-030-14544-6 (eBook)
https://doi.org/10.1007/978-3-030-14544-6

This Springer imprint is published by the registered company Springer Nature Switzerland AG.
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

I am delighted to write the foreword for this book on *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*, edited by Dr. Nayyar and Dr. Kumar. This book is a practical guide that helps you discover the technologies and use cases for Industry 4.0 applications.

The Internet of things, big data and analytics, robotic systems, and additive manufacturing have introduced the buzzwords "Productivity 4.0," "Logistics 4.0," and "Sustainability 4.0" in coherence to this fourth generation of industrial revolution. Integrating physical flows, information flows, and financial flows by adopting smart equipment and intelligent systems for manufacturing and service industries is what defines this paradigm of smart manufacturing and operational excellence with advanced decision technologies. But this industrial Internet presents inevitable new challenges such as cybersecurity, perpetual connectivity, redundancy of jobs, and potentially unexpected environmental derivatives in adopting this as a global business management practice. This book examines the key technological advances that form the pillars of Industry 4.0 and explores their potential technical and economic benefits using examples of real-world applications. It is a comprehensive guide defining the conceptual framework and roadmap for decision-makers for this revolutionary approach.

Moreover, the prospects of sustainable development have started to unfold through the opportunities which Industry 4.0 is providing. For example, socially, Industry 4.0 is already assisting in the efforts to improve human lives and health where manufacturing with big data and analytics together with augmented reality diagnoses patients with health irregularities and ascertain prognosis. More recently, the government reliance on Industry 4.0 technologies has become a part of the digital economy with products and processes like smart cities, 3D printers, market spaces, zero waste, and smart trash. Thus, the maturity and growth of instrumentation, monitoring, and automation as technology drivers support Industry 4.0 is a key to a sharp, viable, competent, and actionable business model. This has compelled the researchers and the practitioners of Industry 4.0 to strive for and integrate the Sustainable Development Goals, or SDGs, such as prosperity, social inclusion, and environmental sustainability. At the same time, to overcome the environmental, economic, and social predicament of the current and the future, the challenges in sustainable development have to be tackled by both advancements of technology and people. This book intends to demonstrate the synergy between the innovations of Industry 4.0, which help making the societies better, saving lives, creating efficiencies, interconnectivity, and ultimately, sustainable

With the changing dynamics of global production, this book will be of interest to academia, industry practitioners, and researchers globally. It is my hope and expectation that this book will provide an effective learning experience and referenced resource for implementation and workforce transformation guiding toward a sustainable, intelligent, innovative, Internet of things industry.

Al-Balqa Applied University
As-Salt, Jordan

Jafar Al-Zubi

Preface

Business innovation and industrial intelligence pave the way to a future in which smart factories, intelligent machines, networked processes, and big data are brought together to foster industrial growth and shift the modalities. *Industry 4.0* or the *industrial Internet of things* is the latest catchphrase of technological innovation in manufacturing with the goal to increase productivity in a flexible and efficient manner. This radical transformation which is changing the way in which manufacturers operate is powered by various foundational technology advances. The creation of "smart factories" using the emergent paradigm of Industry 4.0 includes a fully integrated, automated, and optimized production flow largely based on cyber-physical interaction and its configuration to the Internet of things, big data, and cloud computing.

This book intends to demonstrate the synergy between the innovations of Industry 4.0, which help making societies better, saving lives, creating efficiencies, interconnectivity, and ultimately, sustainable. It offers a primer to understand the paradigm shift of industrial revolution from Industry 1.0 to Industry 4.0, that is, the way business models, strategy formulation and implementation, and management approaches for firms operating in the new outlined scenario are willing to achieve sustainable development and/or foster sustainability. The focus is to comprehend the necessary preconditions, development, and technological aspects that conceptually describe this transformation along with the understanding of practices, models, and real-time experiences to achieve a sustainable smart manufacturing technology. At the same time, the vision is to understand how smart products and Industry 4.0 technologies could generate significant economic, environmental, and social benefits.

The book is organized into 11 chapters. The topics are intelligibly explained with sufficient illustrations, examples, and case studies to reinforce the concepts covered within the text. The primary objective is to address significant fundamental what, how, and why within the domain congregating sustainability to overcome the difficult environmental, economic, and social problems of today and tomorrow, such as:

- What is Industry 4.0?
- What is the current status of the implementation of Industry 4.0?
- How to implement Industry 4.0?
- How do firms exploit Internet of things (IoT), big data, and other emerging technologies to improve production and services, aiming at economic, ecological, and social achievements?
- How to accelerate the implementation of Industry 4.0?
- How is Industry 4.0 changing the landscape of society and workplace?
- Why this unison of the virtual and physical world is needed for smart production engineering environments?
- Why smart production is a game-changing new way of product design and manufacturing?
- How Industry 4.0 ensures sustainable consumption and production patterns?

Chapter "si^3-Industry: A Sustainable, Intelligent, Innovative, Internet-of-Things Industry" aims to provide a comprehensive introduction to the basic concept of Industry 4.0 including its evolution, the principles, building blocks, and the key technologies and concepts around which it is built and is targeted to develop. Chapter "Development of Industry 4.0" explicates allied rudiments of Industry 4.0 such as cross-technological, functional, talent, and business developments from the perspective of real-time scenarios. This chapter also previews detailed knowledge about horizontal-vertical system integration and supply chain that aids in enabling and designing smooth manufacturing process in order to gain more profit. The prospects of sustainable development have started to unfold through the opportunities which Industry 4.0 is providing. It is not viable to discuss about innovation and industry without reference to the three pillars of sustainability, namely the environmental, social, and economic sustainability. Chapter "Sustainable Development in Industry 4.0" discusses this balance between production and the destruction by examining sustainability development in Industry 4.0. Chapter "Big Data and Analytics in Industry 4.0" probes the significance of big data on Industry 4.0 research and practice followed by an in-depth discussion of the new manufacturing paradigm known as ubiquitous manufacturing in chapter "Ubiquitous Manufacturing in the Age of Industry 4.0: A State-of-the-Art Primer." Chapter "si^3-Industry: Cloud Computing in Industry 4.0" primarily concentrates on the contribution of cloud computing over the various industrial sectors. It discusses the cloud infrastructure for industries and presents various independent as well as integrated cloud models.

Chapter "Modeling and Simulation for Industry 4.0" investigates the trending proliferation of Industry 4.0 and design goals which are greatly facilitated by model-based systems engineering (MBSE). It addresses the need for modeling and simulation in Industry 4.0. Chapter "Augmented Reality and Industry 4.0" discusses the basics of augmented reality, its history, types, working, applications, and its emergence into the Industry 4.0. It also identifies various technological requirements for augmented reality in Industry 4.0. Chapter "Robotics and Industry 4.0" discusses the role, various challenges, pros and cons, and various applications of robotics and automation in Industry 4.0. In this current time, the use of additive manufacturing's modern abilities in the domain of IT integration plays a major role in the competitiveness of the industrial domain. Chapter "Additive Manufacturing: Concepts and Technologies" provides a fundamental understanding of the contribution of key elements of additive manufacturing to Industry 4.0. Finally, chapter "Challenges Within the Industry 4.0 Setup" presents the challenges of Industry 4.0 related to the practical aspects, infrastructure requirements, cybersecurity, and business models.

The purpose of this book is to thus confer the preliminaries of the cutting-edge smart technology-driven production maneuver, the Industry 4.0, mainly to determine and verify its potential as a practice which endorses sustainability to ultimately revolutionize the competitiveness of businesses and regions. The highlighting feature of the proposed book is that it will proffer basics to the beginners and at the same time serve as a reference study to advance learners. Also, the book is not country-specific or audience-specific. It will be of interest to academia, industry practitioners, and researchers globally.

Da Nang, Vietnam Anand Nayyar
New Delhi, India Akshi Kumar

Acknowledgments

First and foremost, praises and thanks to the God, the Almighty, for his showers of blessings throughout to complete the project successfully.

I am extremely grateful to my sister, Dr. Sanchi Sharma, for her love, prayers, caring, and continuing support to complete this book project.

Finally, my thanks go to all the authors of chapters who have supported me to complete the edited book project successfully.

Dr. Anand Nayyar

I am most thankful to my family for constantly encouraging me and giving me time and unconditional support while working on this book.

I am extremely grateful to MPS Bhatia, Professor, Netaji Subhas Institute of Technology, Delhi, India, for being a constant source of inspiration throughout my research and teaching career. I will always be indebted to him for his extensive support and guidance. My heartfelt gratitude to the research scholars of Web Research Group at Department of Computer Science and Engineering, Delhi Technological University, Delhi, India, who worked closely with me during the evolution of the book. Lastly, thank you my sonny boy Kiaan Kumar for all the smiles, hugs, and kisses which makes each day a happy day.

Dr. Akshi Kumar

Contents

si³-Industry: A Sustainable, Intelligent, Innovative, Internet-of-Things Industry 1
Akshi Kumar and Anand Nayyar

Development of Industry 4.0 23
Aditi Sharma and Deepak Kumar Jain

Sustainable Development in Industry 4.0 39
Saurabh Raj Sangwan and M. P. S. Bhatia

Big Data and Analytics in Industry 4.0 57
Abhilasha Sharma and Harsh Pandey

Ubiquitous Manufacturing in the Age of Industry 4.0: A State-of-the-Art Primer 73
Pijush Kanti Dutta Pramanik, Bulbul Mukherjee, Saurabh Pal, Bijoy Kumar Upadhyaya, and Shubhendu Dutta

si³-Industry: Cloud Computing in Industry 4.0 113
Bandana Mahapatra

Modeling and Simulation for Industry 4.0 127
Rajalakshmi Krishnamurthi and Adarsh Kumar

Augmented Reality and Industry 4.0 143
Kruti Lavingia and Sudeep Tanwar

Robotics and Industry 4.0 157
Ruchi Goel and Pooja Gupta

Additive Manufacturing: Concepts and Technologies 171
Pimal Khanpara and Sudeep Tanwar

Challenges Within the Industry 4.0 Setup 187
Akshi Kumar and Divya Gupta

Contributors

M. P. S. Bhatia Division of Computer Engineering, Netaji Subhas University of Technology, Delhi, India

Shubhendu Dutta Aujas Networks, New Delhi, India

Ruchi Goel Computer Science Department, Maharaja Agrasen Institute of Technology, GGSIPU University, Rohini, India

Divya Gupta School of Computing Science and Engineering, Galgotias University, Noida, Uttar Pradesh, India

Pooja Gupta Computer Science Department, Maharaja Agrasen Institute of Technology, GGSIPU University, Rohini, India

Deepak Kumar Jain Chongqing University of Posts and Telecommunications Chongqing, Chongqing, China

Pimal Khanpara Department of Computer Science and Engineering, Institute of Technology, Nirma University, Ahmedabad, India

Rajalakshmi Krishnamurthi Department of Computer Science, Jaypee Institute of Information Technology, Noida, India

Adarsh Kumar Department of Systemics, School of Computer Science, The University of Petroleum and Energy Studies, Dehradun, India

Akshi Kumar Department of Computer Science and Engineering, Delhi Technological University, New Delhi, India

Kruti Lavingia Department of Computer Science and Engineering, Institute of Technology, Nirma University, Ahmedabad, India

Bandana Mahapatra School of Data Science, Symbiosis Skills and open University, Pune, Maharashtra, India

Bulbul Mukherjee Bengal Institute of Technology, Kolkata, India

Anand Nayyar Graduate School, Duy Tan University, Da Nang, Vietnam

Saurabh Pal Bengal Institute of Technology, Kolkata, India

Harsh Pandey Department of Electronics and Communication Engineering, Netaji Subhas Institute of Technology, Dwarka, Delhi, India

Pijush Kanti Dutta Pramanik National Institute of Technology, Durgapur, India

Saurabh Raj Sangwan Division of Computer Engineering, Netaji Subhas University of Technology, Delhi, India

Abhilasha Sharma Department of Computer Science and Engineering, Delhi Technological University, Delhi, India

Aditi Sharma DIT University, Dehradun, India

Sudeep Tanwar Department of Computer Science and Engineering, Institute of Technology, Nirma University, Ahmedabad, India

Bijoy Kumar Upadhyaya Tripura Institute of Technology, Agartala, India

si^3-Industry: A Sustainable, Intelligent, Innovative, Internet-of-Things Industry

Akshi Kumar and Anand Nayyar

Abstract

Industry 4.0 is a digital revolution being witnessed in the present generation whereby the aim is to digitize the entire manufacturing process with minimal human or manual intervention. The aim is to encompass as many industries as feasible and adapt and enhance the existing technologies to better suit the needs of digital manufacturing. Concepts like smart manufacturing, smart factories and Industrial Internet of Things (IIoT) are some of the key buzzwords of industry 4.0. The success of industry 4.0 lies to a large extent in successful integration and adaptation of various existing and emerging technologies with the present manufacturing process. This chapter aims to provide a comprehensive introduction to the basic concept of industry 4.0 including how it came up, the principles, building blocks and the key technologies and concepts around which it is built and is targeted to develop. To incorporate or upgrade to industry 4.0, any business or organization must undergo many complicated and time-consuming procedures to transit and incorporate the concepts and strategies of industry 4.0 into their current methodologies and techniques. The aspects of maturity and feasibility with respect to the business scenario are also discussed. Industry 4.0 incorporates technologies from a wide range of domains and in turn demands massive changes like those in innovation, production, logistics and service processes. These are also discussed. The chapter concludes with the concept of sustainability as applicable to industry 4.0.

A. Kumar
Department of Computer Science and Engineering, Delhi Technological University, New Delhi, India
e-mail: akshikumar@dce.ac.in

A. Nayyar (✉)
Graduate School, Duy Tan University, Da Nang, Vietnam
e-mail: anandnayyar@duytan.edu.vn

Keywords

Industry 4.0 · IIOT · UN sustainable goals · Industrial net · Evolution of industrial revolution · Technology pillars of industry 4.0 · Industry 4.0 maturity model

The twenty-first century is currently in the midst of a radical transformation of the way products are manufactured and services are offered. The current generation is witnessing digitization of the manufacturing process and this compelling, significant change in the industry has been labelled as the fourth industrial revolution or Industry 4.0. From mechanization using power generated from water and steam in the first industrial revolution to using electricity for mass production in the second industrial revolution, this fourth phase of the industrial revolution is missioned to take the automation and computerization initiated in the third industrial revolution to the next level of smart manufacturing built on the foundations of artificial intelligence, cloud storage and big data analytics.

Owing to the increasing complexity and demands regarding manufacturing, aspects like rising competition in the international market, rising market instability, and requirement for highly customised products and shortening product life cycle are grave challenges for companies. Seemingly, the existing methodologies of value creation are not enough for handling the growing requirements for price, stability, sustenance, efficiency and adaptation. Industry 4.0, also known as 'smart manufacturing' or the 'industrial internet' can potentially impact the entire manufacturing systems across various industries by bringing about a global transformation regarding the designing, manufacturing, and deliverance of goods and services. Rapid advancements inn digitization and technologies like the internet of things and services, cyber physical systems, big data analytics and cloud computing have assumed a significant relevance.

Hartmut Rauen, Deputy Executive Director Mechanical Engineering Industry Association (VDMA), 2012 says:

A. Nayyar, A. Kumar (eds.), *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-14544-6_1

> The implementation starts with small steps here and there, there won't be a big bang that is going to introduce Industry 4.0. On the contrary, it will come step by step. But if we look back in ten years we will see that the world has changed significantly. [1]

There is no standard definition of industry 4.0 in simplest terms, it is the digital transformation of industrial markets. Below are a few definitions found across literature.

> It indicates the profound transformation of business models by enabling the fusion of virtual and real words and the application of digitization, automation, and robotics in manufacturing. (Gotz and Jankowska [2])

> It is nothing but an autonomous, knowledge and sensor based, self-regulating production systems. (Lasi et al. [3])

1 Genesis of Industry 4.0

The term industry, simply put refers to the production of goods and services within an economy. The various phases of industrialization are ex-post called the various 'industrial revolutions', namely the first, second and third industrial revolutions. Unlike the first three, the fourth industrial revolution is the name given to a planned phase of the industrialization process in accordance with future expectations. The ever-changing demands of the consumers worldwide today is driving global competition. These demands call for a radical change and adaption in the manufacturing process. Amidst all this, Germany, being a leader in the manufacturing sector launched the initiative of 'Industrie 4.0' as part of its high-tech strategy thus bringing forth the idea of a "fully" integrated industry [4, 5]. Ever since, industry 4.0 has gained popularity and attention beyond the borders of Germany and expanded into a global fourth phase of the industrial revolution and listed as key topic in the World Economic Forum's agenda, 2016. It is expected that the success of all industrial nations depend on their active participation in industry 4.0 [6]. This includes participation not only in development but also in marketing and operation of an autonomous, self-adapting production system.

The industrial revolution has origins in the latter half of the eighteenth century. It has come a long way from the first to the fourth industrial revolution popularly termed as industry 4.0. 'Need is the mother of invention' is quite befitting to the ushering of the fourth industrial revolution. The shift and the ever-increasing customer demands and expectations regarding customized products, faster than ever responses and companies' response in fulfilling these and staying competitive are the major role players behind this revolution. Industry 4.0 is a promising emerging ray of hope to meet this end. It combines business, manufacturing, suppliers as well as consumers. Industry 4.0 applies the concepts of Cyber Physical Systems (CPS) and Internet of Things (IoT) to the production process of the industry. These are combined to gather and transmit real-time information with the goal of identifying, locating, tracking, monitoring and optimizing the production processes. Manufacturing Execution Systems (MES) and Enterprise Resource Planning (ERP) can be adapted to provide the required decentralized software control. An important aspect in this regard is the handling of huge amounts of data collected from the numerous machines, processes and products. Cloud storage is used to store the vast amount of collected data. This data needs to be analysed to form decisions which can further be converted into actions (Fig. 1).

1.1 The Genesis: From Then to Now

1.1.1 The First Industrial Revolution (1765)

The pre-industrial era had people majority of people residing in small, countryside communities with their existence and income dependent on agriculture with scanty incomes and prevalent malnourishment and diseases. Bulk of people's food and clothing requirements were produced by themselves and the little manufacturing that was done was done at homes or small shops with the aid of simple hand tools and machines.

Beginning in the latter half of the eighteenth century, the first industrial revolution started in Great Britain and marked the transition from hand production to machines. It introduced the mechanical production equipment driven by water and steam power. Agriculture was replaced. The first mechanical loom was introduced in 1784. Mass coal extraction and development of the steam engine by Thomas Newcomen created a novel energy that empowered all industrial processes. Railroads were developed and economic development gained momentum. Blueprints for factories and cities came into being. People learnt metal-shaping and forging. Iron, coal, textile and steam industries came into being.

The key reasons for Britain being the birthplace of the industrial revolution include its paucity of wood and profusion of coal deposits, business minded aristocracy class, limited government interference, free enterprise system, cheap cotton production by North American slaves, high literacy rate, its prime location in the Atlantic location, its colonies in various parts of the world which provided for cheap land and labour and markets to sell its products. Soon after the industrialization spread to Belgium, Switzerland, France, Germany and the United States.

1.1.2 The Second Industrial Revolution (1870)

The second industrial revolution or the 'Technological Revolution' came into being about a century later, in the latter

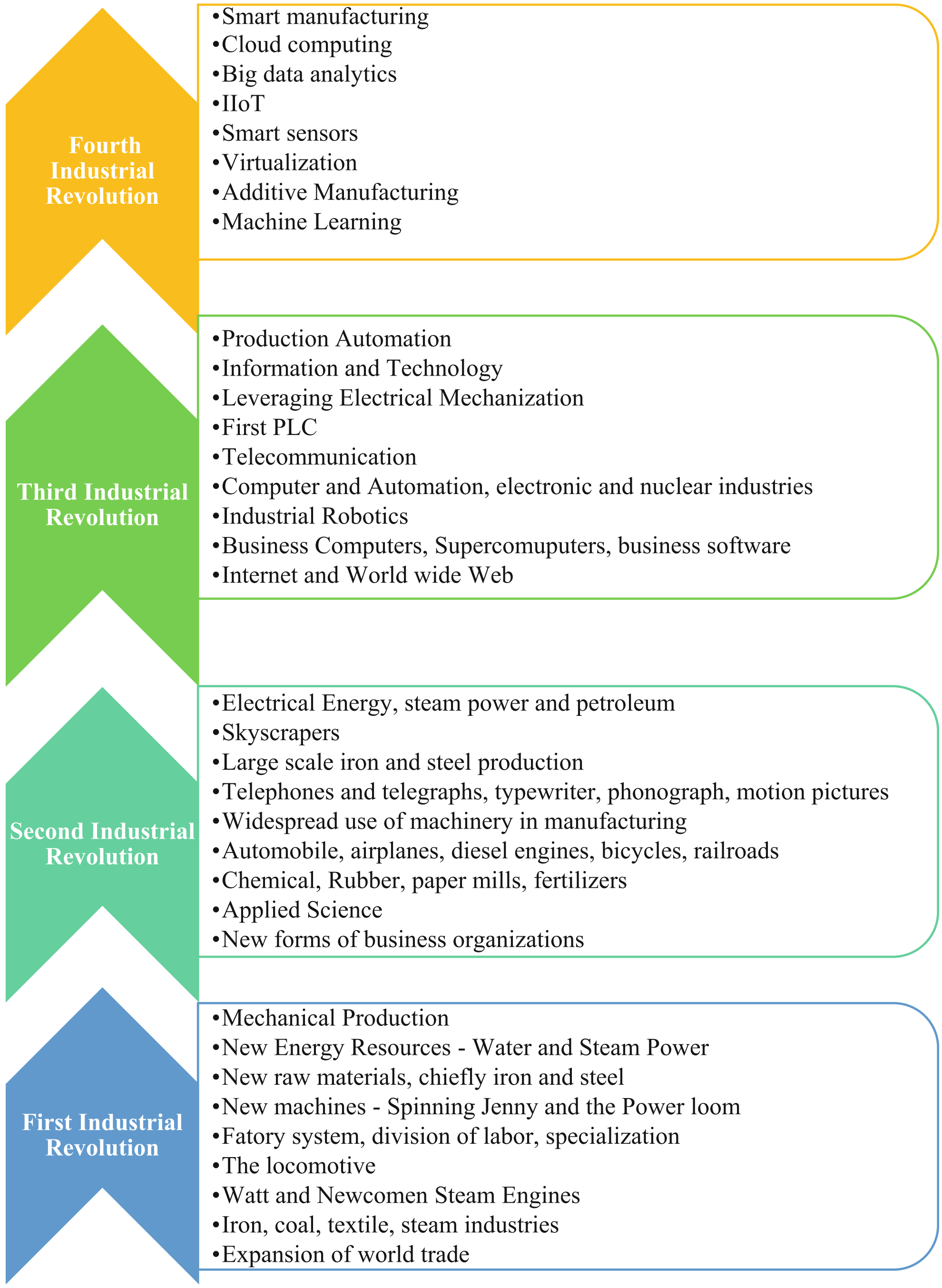


Fig. 1 Phases and key contributions of industrial revolution

half of the nineteenth century. It was a period of rapid industrialization primarily in Great Britain, Germany and the United States, but also in other countries like France, Italy and Japan. Technological advancements and manufacturing in factories enables farmers and manufacturers to produce faster and more goods. Abundance of labour, natural resources, government policies, new emerging sources of power and immigration were some of the key contributing factors for the second phase of the industrial revolution. This phase made use of electrical energy. Mass production was achieved through division of labor. The profound inventions include telephone, telegram, automobiles and planes. Steel industry and chemical synthesis industries like those manufacturing dyes, fertilizers and synthetic fabric came into being. Oil and gas, apart from electricity were being used as energy resources. Steel, automobile and the plane industry were the main highlights.

Transportation, especially the expansion of railroads was a major breakthrough of the second industrial revolution which enabled goods to be easily sent from one place to another. This also allowed expansion of economies which were previously localized. Development of railroads was also a boon for farmers and manufacturers who could now sell their product far and wide. Incredible inventions like the airplane by Wright Brothers, the light bulb by Thomas Edison, the telephone by Alexander Graham Bell were key highlights that surcharged the people with the hope that anything and everything was now possible. The second industrial transformed the map of the United States of America due to unforeseen urbanization and swift territorial extension during the period from 1820 to 1860.

On the flip side, the second industrial revolution also gave rise to widespread poverty, unemployment with humans being replaced by machines, deep depression and prevalent economic insecurity. The great depression during the 1870s and 90s made millions jobless or those who retained their jobs were forced to work with reduced pay. Working conditions in the industries were dangerous with stretched working hours and no compensation for overtime and injuries. Skilled workers, on the other hand got high pay and economic independence. The second industrial revolution ended with the onset of World War I.

1.1.3 The Third Industrial Revolution (1969)

About a century later, the third industrial revolution paved its way. With this revolution, ushered in electronics and computers, the aim being production automation. Telecommunication was introduced. The first Programmable Logic Controller (PLC) was introduced in 1870. PLCs were being used by factories for production. Robots came into being. The introduction and use of nuclear energy made this revolution exceed its two predecessor revolutions. The three primary, in focus industries being the computer and automation industry, electronic and nuclear energy industry, paved way for the emergence of Internet and soon after the fourth industrial revolution.

1.1.4 The Fourth Industrial Revolution (Now)

The twenty-first century is presently witnessing the fourth industrial revolution, popularly known as 'Industry 4.0'. It is based on the concept of smart manufacturing. The vision is to use digitization to design, build and develop an empowered virtual world that would steer the physical world. The aim is to interconnect all production and enable their real-time interaction. Cloud computing, big data analytics, Industrial Internet of Things (IIoT) and cyber physical systems are the key technological foundations for this industrial revolution.

Although, the first initiative for the transition to Industry 4.0 comes from Germany, similar concepts were introduced in countries worldwide. General Electric brought the concept of the 'Industrial Internet' in North America in late 2012 as a tight incorporation of the physical and virtual worlds based on a combination of IoT and big data analytics. This concept covers a wide range of domains like distribution and generation of power, the health industry, transportation industry, the various public sectors, manufacturing and mining [7]. The concept of 'Industrie du futur' was presented in France as the foundation of the future industrial revolution in France. It is based on five pillars namely cutting edge technologies, support for small and middle French companies, extensive training of workers, consolidation of international cooperation based on industrial principles and promotion of the French industry [8]. In 2015, the 'Made in China 2025' initiative by the China Ministry of Industry and Information Technology in cooperation with experts from the China Academy of Engineering was introduced [9]. The prime goal being to comprehensive upgradation of the Chinese industry by inspiration from Germany's initiative and its adaption to Chinese needs. The long term goal being to transit from low-cost to high-quality products and become the industrial word superpower till 2049.

Two development directions govern this future project of industry 4.0. The first being an application pull, triggered by short development periods, individualization on demand, flexibility, decentralization, and resource efficiency. The other direction being the current technology pull owing to increasing mechanization and automation, digitalization and networking, and miniaturization [3].

Design Principles

There are four key Design Principles underlying Industry 4.0 shown in Fig. 2, namely interconnection, information transparency, technical assistance, and decentralized decisions [10].

- *Interconnection*: A foundational principle of Industry 4.0 is to interconnect and make various machines, cyber physical systems, sensors, devices and people so that they can interact and exchange data, which is later analysed and transformed to information that would aid decision making and ultimately set various production processes into action.
- *Information Transparency*: Transparency would provide useful information to various operators thus enabling them to make more efficient decisions. A large amount of data can be made available as a result of interconnection of various devices, people and technologies thereby enhancing functionality, driving innovation and aiding improvement.
- *Technical Assistance*: Assistance systems can collect and visualize the information gathered thus assisting humans not only in making more efficient and informed decisions, but also in solving urgent issues on short notice.
- *Decentralized Decisions*: Cyber physical systems have the ability to make autonomous decisions barring exceptional situations, wherein the decision making is delegated to the higher levels.

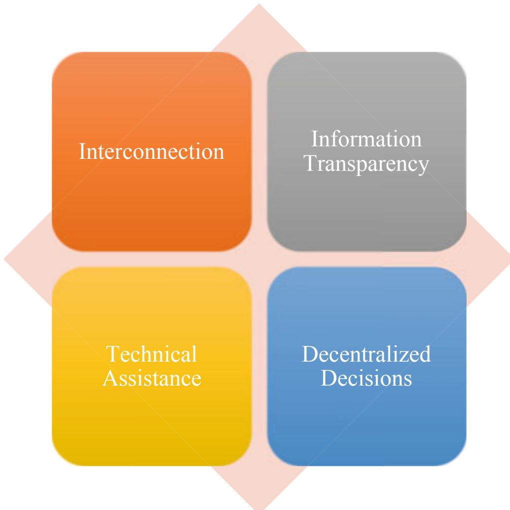


Fig. 2 Design principles of Industry 4.0

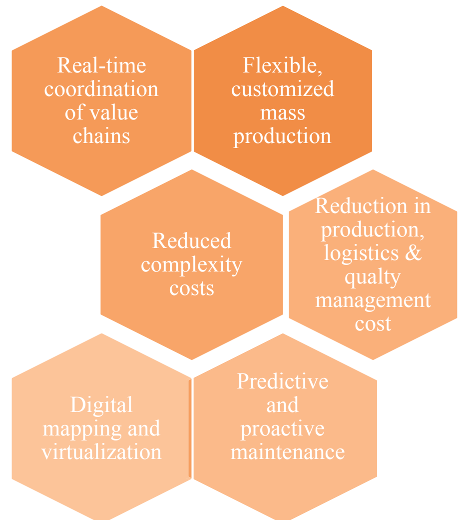


Fig. 3 Advantages of Industry 4.0

Industry 4.0 offers manifold opportunities, breakthroughs and advantages like highly adaptive, flexible and customized mass production, coordination of value chains in real-time and their optimization, reduced complexity costs and emerging new service and business models. Figure 3 represents the benefits of Industry 4.0. It is anticipated to bring about reduction in production and logistic costs by 10–30% and costs in quality management by 10–20% [11], shorter marketing time, better customer responsiveness, mass production at lower costs, flexible and friendlier working environment, efficient use of natural resources [12]. It will enable to completely utilize the potential of new and emerging technologies and concepts. It will enable digital mapping, wide scale and real time virtualization along with predictive and proactive maintenance that will enable to predict and plan unplanned downtime, potential risks and faults and failures. It will allow experts to monitor and direct industrial processes from remote locations and usher in the effective and efficient use of collaborative technologies.

Next section will uncover the building blocks of Industry 4.0. Then Sect. 3, will elaborate on the feasibility and maturity of Industry 4.0 Net, followed by the Changing roles of innovation, production, logistics, and the service processes and at last the UN's sustainable development goals will be discussed.

2 Building Blocks of Industry 4.0

Industry 4.0 is on the verge of changing the way we place orders and the way manufacturing of products is being done. This new revolution is built on the current technologies which we are being using in current industries too (Industry 3.0), just the way to utilize these technologies has been reorganised to provide superior coordinated services. There are two broad foundations of the industry 4.0, one based on the technologies or the software's and the second one based on the physical elements or hardware. First, the hardware or the basic four physical elements are being discussed that set the foundation of Industry 4.0.

2.1 Smart Sensors

Smart sensors are the founding stones of the Industry 4.0, as industry 4.0 is a revolution surrounded around IOT & CPS, sensors are the one that perform a wide range of functions to provide the support to these technologies. Therefore, smart sensors are the first layer in developing stones in industry 4.0 as shown in Fig. 4. Smart sensors act as the manufacturing assets that can virtually gather big data about the products and their environment, e.g. it can measure temperature, humidity and smoke in the air. Sensors can provide the capability to communicate wirelessly and data can also be synthesized using a cloud based interface. Sensors can also detect anomalous activities.

2.2 Controls

Control systems monitors the working condition of manufacturing machines and any critical events. They serve as the brain of the manufacturing process. The control systems implemented in a manufacturing facility is often centralized or de-centralized. Subsystems like data acquisition systems, sensor network, actuators and control devices are highly involved in the control system for manufacturing.

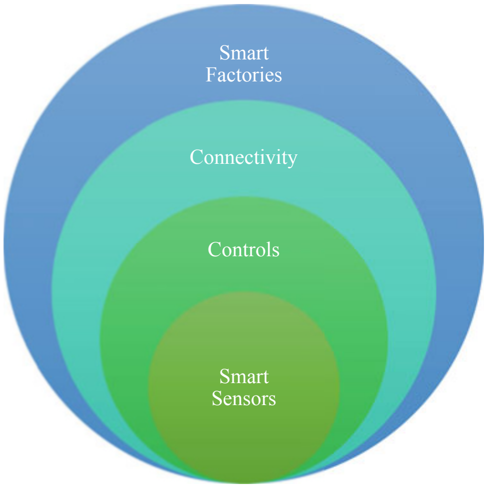


Fig. 4 Building blocks of Industry 4.0

Recently, the control systems are involved in monitoring energy consumption in a real-time manufacturing environment.

2.3 Connectivity

Controls oversees the working conditions and the process of data acquisition by sensors, but this data is of no use if not communicated to the centralized server or the decision makers. This communication between devices is possible through connectivity and networking, and this connectivity is provided using the Internet and include various technologies like routers, servers, switches, Ethernet, gateway devices and Linking technologies. The very foundation of industry 4.0 is the concept of everything connected, so when an order is received by one device, all other are shared the information through the shared medium, every machine or robot will start work on its part, creating a fully functional optimized Supply Chain 4.0 (discussed in next chapter). Mobile devices can play a pivotal role in providing connectivity among devices. Communication is like the blood flow of industry 4.0 and the telecommunication can play an important part in it.

2.4 Smart Factory

Smart factory is the heart of industry 4.0. The whole concept of new revolution business, product, machines, sales are either part of or depends on the smart factory. Smart factories have large control over themselves and provides a flexible system enabling self-optimization of performance across wide ranging network and self-adaptation allowing learning from real-time conditions. They also have the potential to autonomously run entire production processes.

In Martin's words "The Smart Factory can be defined as a factory where CPS communicate over the IoT and assist people and machines in the execution of their tasks" [4]. In simple terms a smart factory is a factory where smart machines work to produce smart products. In future, the smart factories will not only be able to manufacture, but will deliver the product too. As the communication between machine and product and the trucks or other devices which will carry the products for delivery will be interconnected by the CPS and will communicate through the IoT, they all are used inside Smart Factory.

Smart sensors, controls, Connectivity and the smart factories are the necessity to set up an manufacturing industry to the current revolution. The technologies that are incorporated by this revolution are known as the nine pillars of Industry 4.0 as shown in Fig. 5. The key concepts and technologies involved in industry 4.0 are as follows:

Cyber Physical System

Cyber physical or cyber physical production systems (CPS) are the ones that connect with the real physical world [12]. CPS together with the IOT is often used for merging the physical world with the virtual world. Together, they aim to accomplish the production of more intelligent smart factories which could further lead to enhanced and smart production thus enabling faster and efficient digitations. The emergence and development of CPS technology will promote open-ended industrial innovations [13–16] including energy production, transport, logistics, machinery, heavy industry, iron, steel metallurgy etc.

Cloud Computing

Cloud Computing has emerged as a computing paradigm that imparts varied Internet services in a high cost efficient manner [13, 14, 17] to the users. These are quite compatible for dynamic memory allocation and resource sharing, enabling users to use the cloud resources as per their needs including hardware, software, infrastructure resources etc. It would enable real-time data exchange thus enabling the creation of digital collaborated and integrated environment. It would allow better stakeholder connectivity and real-time visibility of data enabling proactive supply chain management.

Industrial Internet of Things (IIOT)

Industrial Internet of things (IIOT) is associated with the concept of virtual world. Blending of the physical world with the virtual world has been made possible with the help of technological innovations in the field of IOT [18]. IIOT is a subset of IoT, focuses on industrial automation, device

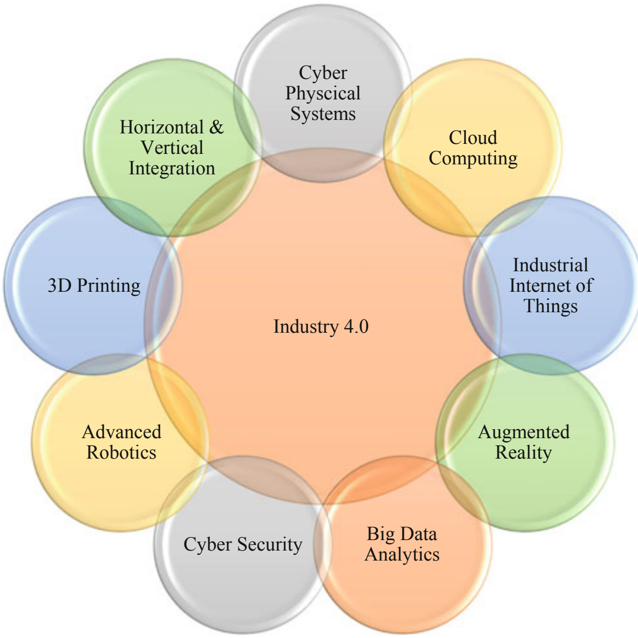


Fig. 5 Technology pillars of Industry 4.0

communication, data flow, device administration, device integration, and predictive analytics [19–22]. It includes laser scanners, global positioning systems, sensors etc. IIoT will help to decrease the complexity of machine-to-machine communications and would allow collection and analysis of data using strategically positioned sensors.

Augmented Reality
Different variety of services including selection of parts in warehouse, conveying instructions related to repair of the mobile devices etc. are provided with the help of augmented reality based systems [13, 14, 17]. They aim to furnish the real time information that could be used by workers etc. for effective and efficient decision making procedures. Objects in complex projects in industry 4.0 can be easily virtualized by augment reality technology. Moreover, the virtual models are easily shareable and understandable in between the cycles of development.

Big Data Analytics
Big data technology is used for gaining proper insight in order to fetch relevant information from heterogeneous and unstructured online available Web data. Utilizing the advantages of big data, together with the data mining techniques and data analytics, can serve as a boom for better analyzing the data and eventually aid in the production process. Proper collision of these technologies would promote benefits to manufacturing companies including optimizing the process, cost reduction and provides improvement in the operational processing and would directly enhance the profits of industry 4.0 [13, 14, 17]. Big data analytics will help increase reliability and efficiency by predicting critical situations and enabling real-time interventions.

Cyber Security
Cyber security is the branch of computation technology that provides protection to computer systems from theft or damage to hardware, software or information and from disruption of the services provided. Integration of human machine interfaces with the industry would not only increase efficiency, but would also aid in monitoring the communication between human and machines. If this information gets in wrong hand, it can be used for dreadful reasons. To make the industry 4.0 safe for everyone's use, cyber security protocols are enforced.

Advanced Robots
Robots can be very useful for tasks like predictive maintenance. They can monitor the conditions of machines, perform comparative analysis and diagnose and predict machine failures. The collaborative robotics (Cobot) belongs to a new generation of robotics [13, 14, 17] that work in a very cooperative manner with the humans without requiring any security restrictions etc. These are programmed for better accessibility flexibility and ease of use.

3D Printing
3D Printing can enable mass production of highly customized products. Inventory digitalization can lead to significant cost savings. This often includes 3D printing etc. that are used for production of individual components. With the augment of Industry 4.0, this technology would gain fruitful impact and boost the production of customized and personalized products [13, 14, 17] by the manufacturers.

Horizontal and Vertical Integration
There are multiple factors involved in any successful business including quality development, efficient marketing, distributors and suppliers and most importantly customers and the competitors. Smart factories in the new revolution tries to interconnect the machines, materials and the products [16]. To take the business to the up-most level, all the factors contributing to it should have effective communication. Industry 4.0 has therefore Horizontal and Vertical system integration to make the manufacturing process even more smooth.

Industry 4.0 is built on these nine pillars of technology to provide a customizable environment to the end users. These nine technologies with the four building blocks of industry 4.0 enables the production process to adapt to various customer requirements in an agile development process providing a flexible manufacturing process. These days, markets are customer-centric [23]. In order to stay competitive and worthwhile, manufactures/companies ought to act accordingly as per the customer's rapidly changing needs. All this is creating a variable and viable demand pattern in the upcoming manufacturing technology [13, 14, 17]. The manufactures are thus, required to manufacture the stuff as demanded by the customer, relying together with the agility and sequencing depending on the latest technologies.

3 Maturity and Feasibility of Industrial Net

Organizations that change their businesses and tasks in regards to Industry 4.0 standards face complicated procedures and large spending plans because of technologies on which they are dependent that affect inputs and outputs. Furthermore, since Industry 4.0 transformation makes an adjustment in a business way and incentive, it turns out to be very crucial concept that requires backing of top administration for ventures and for speculations/investments. In this way, it needs an expansive viewpoint on the organization's system, association, tasks and items. Maturity and Feasibility are two such terms in the concept of industry 4.0 that defines the ways to analyze the development of one's business and the potential that any organization has for the progress of its development. Scientists hold distinctive feelings of the particular need of Industry 4.0 and its achievement, and thus following up on their various applications of modern technology [24–28].

3.1 Industry 4.0: Maturity

As a rule, the word "Maturity" means a "condition of being complete, impeccable, or prepared" [29] and infers some advancement in the progress of a framework/system. Likewise, developing frameworks (for example natural, authoritative or mechanical) increment their abilities over time with respect to the accomplishment of a few desirable future states. Maturity can be caught quantitatively or on the other hand qualitatively in a continuous or discrete way [30].

Maturity models are generally used as a tool to understand and measure the maturity of a company/organization or a way to analyze some particular target state [31]. Maturity models are appropriate for organizations intending to change their businesses and activities specifically for Industry 4.0 [28]. It is an imperative procedure for Industry 4.0 as far as organizations looking for surveying their procedures, items and associations and understanding their development level. Here, we look into some existing maturity models for Industry 4.0 and they are described further.

Table 1 Levels of IMPULS model

Level	Designation
0	Outsider
1	Beginner
2	Intermediate
3	Experienced
4	Expert
5	Top performer

IMPULS—Industrie 4.0 Readiness (2015) Researchers in [32] performed experiments and literature studies for Industry 4.0 to develop a readiness model for Industry 4.0. The six levels of readiness in the model of Industry 4.0 is given below in Table 1.

In this work further, workshops were conducted and this subsisting readiness or feasibility model was shaped in six dimensions of Industry 4.0 as shown below in the Table 2. Evaluation review contains questions, for related dimensions, that were 24 in number also a couple of inquiries regarding industry, size of residential workforce and yearly income. So as to quantify and characterize status of industry 4.0, Likert scale of 5 point is utilized.

Organization status are assembled in three categories to abridge results in a better way [32], for example, Newcomers with level 0 and 1, Learners with level 2 and Leaders with level 3 and up. Newcomers comprise of organizations that have not ever instated any activities or have contemplated a couple of tasks. Learners comprise a gathering of organizations that introduced first ventures identified with Industry 4.0. Leaders is a gathering that contains level 3, 4 or 5 organizations which are path in front of different organizations about Industry 4.0 usage.

Industry 4.0/Digital Operations Self-assessment A report titled "Industry 4.0: Building the advanced venture" was distributed by PwC to give organizations complete point of view on Industrial net of 4.0 by speaking to its own models for maturity and plan for success.

In the starting phase of "Plan for Digital Success", A basic maturity model was given by PwC to the organizations in order to analyze their capacities which consisted of four phases and seven dimensions. Stages are defined as underneath:

- 1st Stage: Digital novice
- 2nd Stage: Vertical integrator
- 3rd Stage: Horizontal collaborator
- 4th Stage: Digital champion.

Seven dimensions were used to evaluate organizations' maturity levels by PwC, for example, "Digital business

Table 2 Industry 4.0: dimensions and associated fields

Dimensions	Associated fields
Strategy and organization	Strategy Innovation management Investments
Smart factory	Digital modeling Equipment infrastructure Data usage IT systems
Smart operations	Cloud usage IT security Autonomous process information sharing
Smart products	Data analytics in usage phase ICT add-on functionalities
Data driven services	Share of data used Share of revenues Data-driven-services
Employees	Skill acquisition Employee skill sets

models and customer access", "Digitization of product and service offerings", "Digitization and integration of vertical and horizontal value chains", "Data and Analytics as core capability", "Agile IT architecture", "Compliance, security, legal and tax", "Organization, employees and digital culture". PwC empowers organizations to evaluate their maturity of Industry 4.0 and guide their outcomes by online self-assessment tools. In the last phase of evaluation, PwC gives organizations an action plan to make them effectively achieve better level Industry 4.0 maturity. Online self-assessment tool as explained in [33] has 33 inquiries altogether for related dimensions and a couple of inquiries regarding industry, locale, nation and yearly income to characterize organizations. Likert scale with five points is utilized for every inquiry and radar realistic is given at the end of the evaluation.

The Connected Enterprise Maturity Model (2016) Rockwell Automation created the maturity model named Connected Enterprise in 2014 and this model consisted of five phases and four dimensions that were innovation centered. Stages in this model are given below [31]:

- 1st Stage: Evaluation/Assessment
- 2nd Stage: Upgraded and secure controls and network
- 3rd Stage: Organized and defined working information capital
- 4th Stage: Analytics
- 5th Stage: Collaboration

The Stage1 assesses all aspects of an association's current OT/IT (Operational Technologies/Information Technologies) network with four dimensions, and they are

- Information infrastructure
- Controls and devices
- Networks
- Security policies

In Stage 2, Operational technologies/Informational Technologies relation is being shaped in order to convey safe, versatile network between undertaking business frameworks and plant-floor tasks after an evaluation stage. Large haul updates start and gaps and demerits of existing tasks are distinguished. In large scale organizations, obsolete control and framework form a hurdle in path of change as well as delays from administrators and architects which has a mindset that present frameworks stay suitable.

In Stage 3 there is nothing peculiar but the enhancement developed with present information is in advancement with previous stage. This stage has a task of determining how the gathered information will be prepared and what are the ways so that ideal results can be obtained. Organized group guarantees that new work processes, outlines and duties are set with the goal of not overpowering by the organization information pool.

From Stage 4, the utmost interest is on the idea of continuous improvement over data. Analytics using WDC (working data capital) will help in order to determine specifically the best requirements for data of real-time and provides guarantee for the coherence of institutionalized rules activated by the means of information. Also, the analytics give data exchange about resource cooperation for leadership group. Problems that occur in Stage 4 will be utilization of bunches of superfluous information and doubt of examination. Fundamental thought is to furnish cooperation among organization and environment with the assistance of analytics and information sharing in stage 5.

Industry 4.0 Maturity Model (2016) 9 dimensions and 62 maturity items were utilized by Schumacher et al. in [34] so as to evaluate organizations Industry 4.0 maturity levels. The Maturity items and dimensions are given in Table 3.

These levels are inspected under five levels. As per the model, for level 1, the organizations do not have much knowledge and benefitting ideas for industry 4.0 whereas every requirement can be meet by level 5 organizations. Here, 5 point Likert scale is used for performing evaluation of surveys. After performing surveys, weighted focuses are determined and levels of maturity of organizations are resolved. By understanding all the models explained above, we can thus summarize that maturity models are a way to check the progress of development of the business with respect to the required industry 4.0 net. Three basic steps as defined below in Fig. 6 can be used to access the maturity of Industry 4.0. After this, the analysis of maturity

Table 3 Maturity model of Industry 4.0: dimensions and maturity items [34]

Dimensions	Exemplary maturity item
Strategy	Implementation I40 (Industry 4.0) roadmap, available resources for realization, adaption of business models, . . .
Leadership	Willingness of leaders, management competences and methods, existence of central coordination for I40, . . .
Customers	Utilization of customer data, digitalization of sales/services, costumer's digital media competence, . . .
Products	Individualization of products, digitalization of products, product integration into other systems, . . .
Operations	Decentralization of processes, modeling and simulation, interdisciplinary, interdepartmental collaboration, . . .
Culture	Knowledge sharing, open-innovation and cross company collaboration, value of ICT in company, . . .
People	ICT competences of employees, openness of employees to new technology, autonomy of employees, . . .
Governance	Labor regulations for I40, suitability of technological standards, protection of intellectual property, . . .
Technology	Existence of modern ICT, utilization of mobile devices, utilization of machine-to-machine communication, . . .

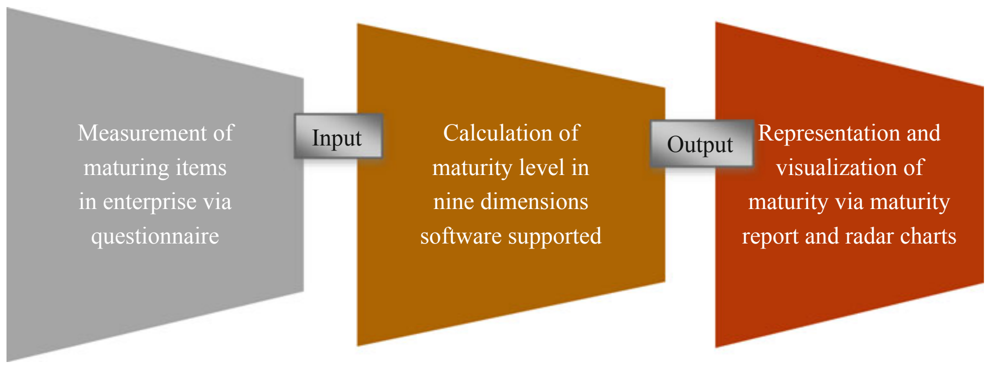


Fig. 6 Industry 4.0 maturity assessment process flow

within an organization is performed using the maturity products by utilizing a standard enquiry/questionnaire comprising of one closed-ended enquiry per product/item [34].

Finally the maturity level of every dimension is determined which is done using the equation represented below.

$$M_d = \frac{\sum_{j=1}^{n} M_{dIj} * w_{dIj}}{\sum_{j=1}^{n} w_{dIj}}$$

where, "M" represents "Maturity", "d" defines "Dimension", "I" indicates "Item", "w" represents "Weighting Factor" and "n" shows the "count of Maturity Item" [34, 35].

3.2 Industry 4.0: Feasibility

A feasibility study will give anyone the order and knowledge to promise oneself that one's thought is beneficial pursuing [36–38]. Moreover, in the event that one has to fund his/her business 4.0 environment, loaning establishments and investors, normally require a feasibility study. The feasibility study assesses the project's potential for progress. The dimensionality of the Feasibility analysis is shown below in Fig. 7.

There are typically three segments to the possibility contemplate, be that as it may, contingent upon your business; the specialized examination may not be required.

- Analysis of Market
- Analysis of Technology
- Analysis of Finance

Notwithstanding the market analysis, the financial evaluation is a basic segment of the feasibility study. Without the "financials" it will be difficult to decide how feasible the business thought is. Incorporated into the financial evaluation is income and expenses to decide the level of risk for your investment/speculation. Key segments of the financial evaluation include [39, 40]:

- Capital Needs
- Costs of Implementation
- Projections of revenue
- Gross Profit Margins (GPM)

The data that has been produced and evaluated by the feasibility analysis prompts an appraisal workshop for the decision makers [41, 42]. As per this essential data about the advanced digital changes opportunities risks and expenses of

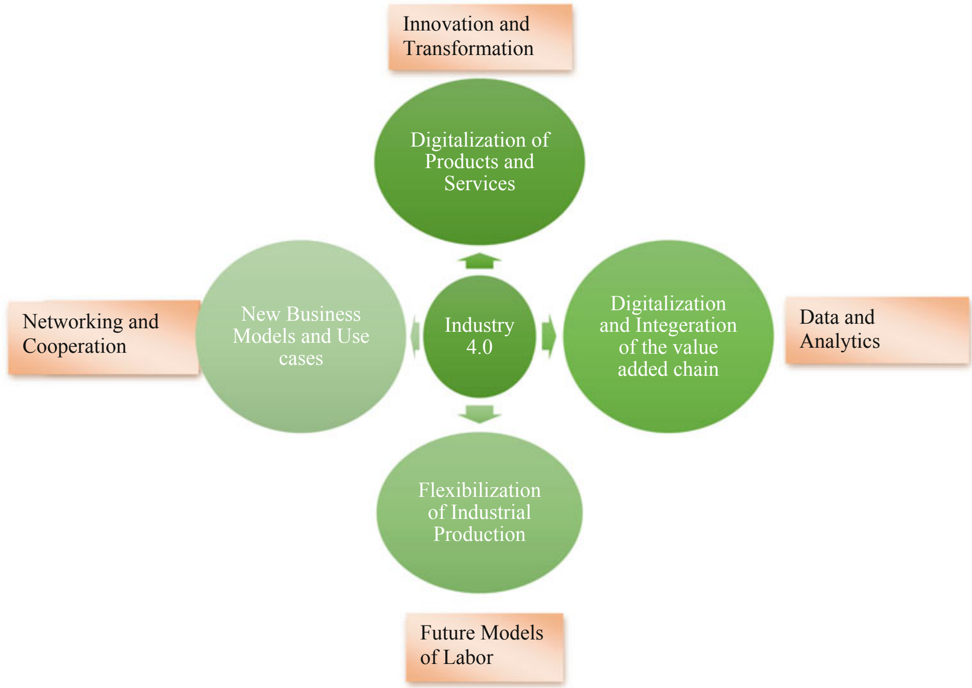


Fig. 7 Industry 4.0: feasibility analysis

IoT ventures/projects can be limited. A GO or NO GO for propelling the IoT/Industry 4.0 task and distinguishing the most significant combination openings can be acknowledged in a least amount of time.

4 Changing Roles of Innovation, Production, Logistics, and the Service Processes

Our present technological age, the fourth industrial revolution is a fusion of technologies ranging from physical, digital to biological spheres. It is marked by diverse technological breakthroughs that bring together the field of robotics, artificial intelligence, nanotechnology, biotechnology and a lot others. In short, industry 4.0 describes the huge changes brought about by the smart technologies [43]. These changes are posing change management challenges to the companies. The most important areas which are facing these changes are innovation, production, logistics, and the service processes. The changing roles of these fields are described in this section.

4.1 Innovation

The industrial revolution's standard timeline is shown in Fig. 8. The first phase is known as Industry 1.0 which had its focus on steam and water potential. The advent of electrical energy in nineteenth century gave rise to Industry 2.0.

Industry 3.0 was a result of electronics and information technology (IT) during 1970s which focused on automation, electronics and computers. At this point of time, we are witnessing the phase of transition from Industry 3.0 to Industry 4.0.

Increased pace of innovation is a result of the revolutionary period of transition to Industry 4.0. Due to the unprecedented change, more and more radical innovations are emerging. Earlier, the business models used to be product centric but now they need to be focused on development of new value sources. Therefore, the innovation has a completely different focus now which in turn changes its role. Connectivity is one of the most important fields of innovation when it comes to the fourth industrial revolution, be it the machine-machine connectivity, machine-human connectivity or human-human connectivity [44]. For example, closer a manufacturer is to his/her customer, more satisfied both of them will be. In other words, an efficient connectivity between the virtual world and the physical world is an important aspect of innovation in Industry 4.0. Now innovation is more technology based. Innovation is increasing in the field of exploration of entirely new business models. Broadly, the focus of innovation is changing in the following five fields as shown in Fig. 9: Technological innovation, government innovation, innovation systems, business model innovation, innovation for social ends and means [45]. These can be further classified as shown in Fig. 10.

Industry 4.0 has made innovation very interconnected as shown in Fig. 9. Earlier innovation used to be single domain

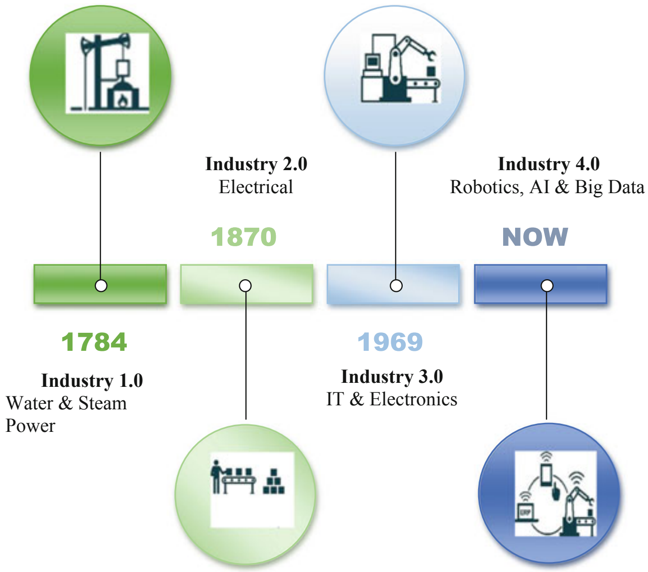


Fig. 8 Four industrial revolutions

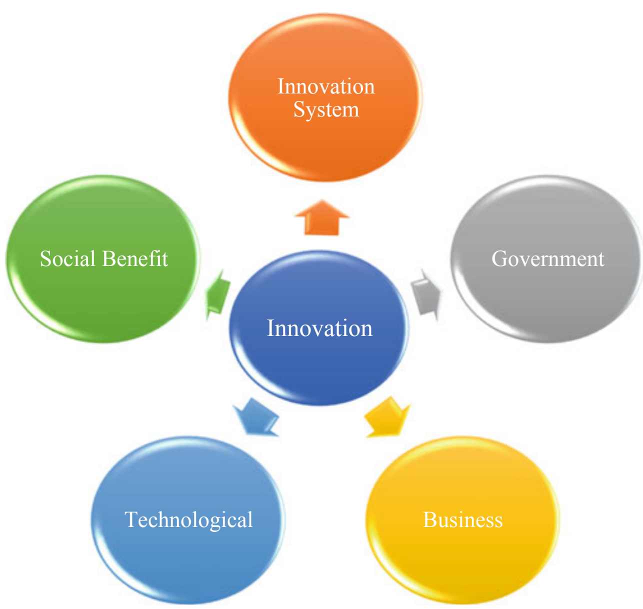


Fig. 9 Innovation focus in Industry 4.0

specific. This is continuously changing due to this revolution. Instead of being focused on only the final product, now innovation has a great role to play at every step of product development cycle. This has broadened the innovation canvas to be worked upon. Industry 4.0 is making innovators to think out of the box. They need to shift their focus on connecting every part. Industry 4.0 has a huge potential to transform the way innovation is moving forward. A dramatic change in innovation management and the way innovators think is being experienced in the fourth industrial revolution. In other words, innovation is going through a radical change.

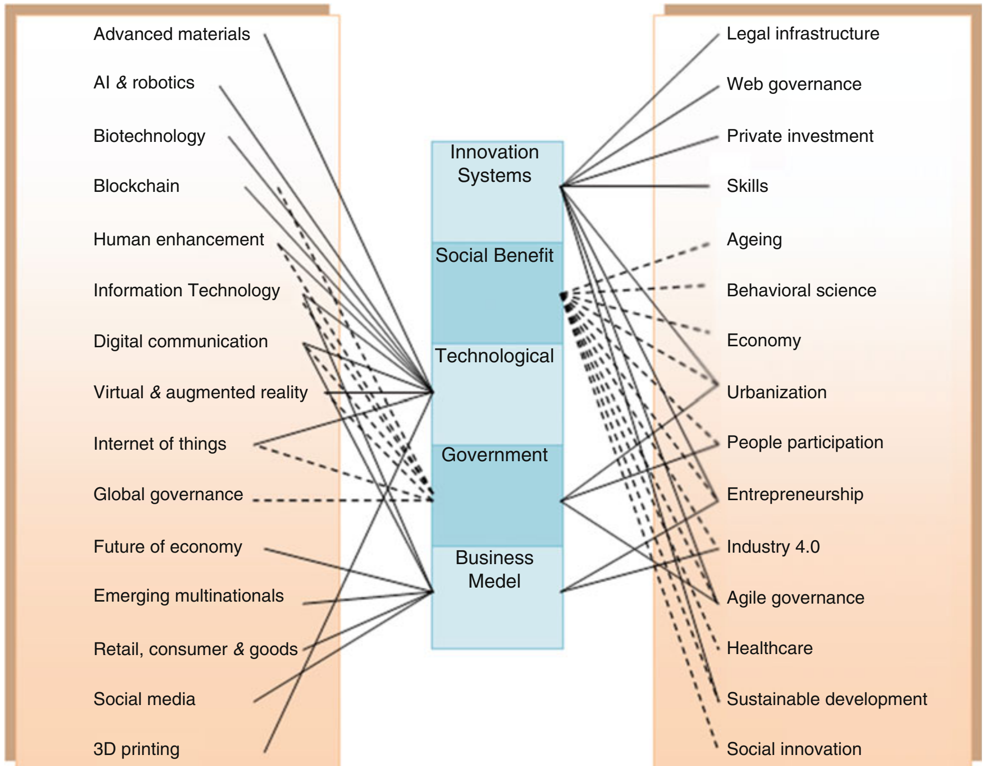
4.2 Production

Industry 4.0 can also be defined as a movement towards smart production. Therefore, the role of production is also undergoing various changes. National Institute of Standards and Technology defines smart manufacturing as fully integrated, collaborative manufacturing systems that respond in real time to meet changing demands and conditions in the factory, in the supply network and in customer needs. Adopting Industry 4.0 requires both vertical and horizontal integration of data across the business. Vertical digitalization may include production, procurement, supply chain, design, product life cycle management, quality, operations and logistics. All integrated for a smooth flow of data. Horizontal digitalization may include data integration with customers, suppliers and key partners. Achieving integration requires replacing or upgrading equipment's, processes and networks until an efficient digital ecosystem is attained. Efficient data services and analytics is also a major requirement of production to convert the information being generated by the machines, sensors and systems into insights which can provide an investment return. Connected systems increase the risk of cyber security. IT experts play a very important role in production when Industry 4.0 is adopted as they can check whether the best practices of cyber security are being followed or not.

In order to successfully adopt smart production, an investment in education and required technology is must. The nine technologies which are playing important roles in transforming production in Industry 4.0 are shown in Fig. 11.

3D printing is an example of an entity which has the potential to realize Industry 4.0. In spite of being a very simple technology, it can make huge transformations in modern production. A 3D printer enables one to take a digital blueprint which gets into the system as an input and the system transforms the same to be used by printer. Then, the physical printer develops the item which has been detailed. This is done using materials such as hard ABS plastic, metal, concrete and more. In this way the entire production industry effectively transforms [46]. 3D printing also enables one to use remote locations for printing from where customers can order. It makes smart production very different from traditional practices. This is just one example of such technologies. There are many others such as automation which have the potential to completely transform the production process and provide a boost to Industry 4.0. Most of the changes which are happening in production are focused on

Fig. 10 Innovation fields



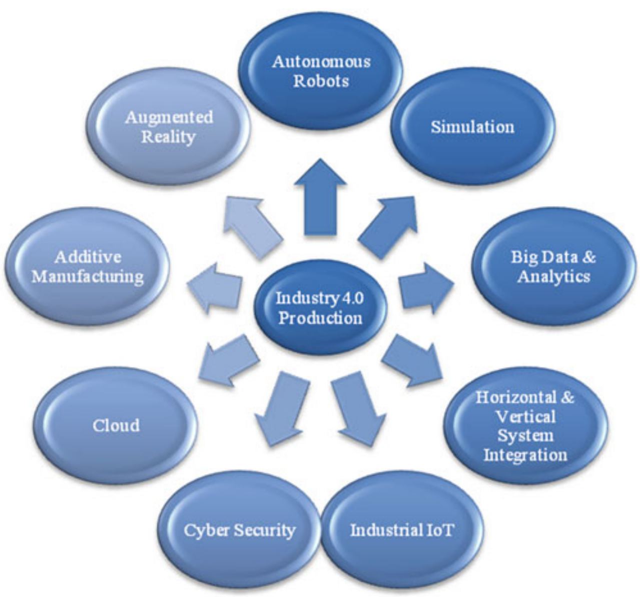


Fig. 11 Nine technologies transforming production in Industry 4.0

customization i.e., developing more personalized products for consumers. Consumer involvement has increased in Industry 4.0. Earlier it was impossible due to lack of many technologies and hardware. Now development is revolving around the clients. To cope up with Industry 4.0, manufacturers should invest in training, automation of processes, devices and software. In this revolution production is agile. There is a need of customization of product development life cycle, quick delivery and improved functionality.

4.3 Logistics

Innovation and time are the main competitive advantages. Time, here, is understood as the frequency of the introduction of upgraded or new versions of a service or product. Its growth shortens the life cycle of such products in comparison to traditional products. The different phases of the life cycle are short in-time and rapid demand-dimension [47]. There are several ways to define logistics but in context of Industry 4.0, it can be seen as getting everything done from start to end with a large number of intermediary steps and the movement and communication across all steps must be intelligent and autonomous. For example, smart containers, driverless vehicles, smart ports, intelligent warehousing, smart information sharing. Logistics in Industry 4.0 are self-managing where objects are smart and capable enough that they can decide their path on their own and that too in a cost effective way. Also, these smart objects such as containers can order required resources autonomously. One of the most common demands of Industry 4.0 is highly personalized services. With changing demands, logistics also need to adapt accordingly. Increasing complexity is making it impossible to handle the logistics with traditional practices [39]. Now logistics are required to be more flexible and able to adjust to the changing environment in order to fulfil the needs of customers. More optimized production will lead to decrease in the cost of storage and manufacturing. Smart logistics aim to improve the customer service. In Industry 4.0 logistics transform with the development of technologies. It can be said that it has a dependency on time. Therefore, defining technology's state of the art becomes essential [48]. This shift in the role of logistics is a result of advanced digitalization. I order to cope up with Industry 4.0, logistics professionals should focus on developing the following skills:

1. Knowledge of the latest technologies
2. Change management skill
3. Knowledge of company/organization across the value chain

Logistics department of organizations should make their employees ready and prepared for Industry 4.0. This might require new collaborations and hiring. Industry 4.0 is affecting how logistics used to operate. As logistics deal with the way of doing things, therefore, when its role changes, one needs to be very careful. A technology will be successful only when an organization has the talent to make full use of it. The following are the main factors which play important role in changing logistics:

- Talent requirement is the most important pillar of strengthening logistics.
- Implementation of technology can affect all aspects of logistics. Workforce should be kept in a close loop while implementing new technologies.
- Another important factor is change management which requires efficient training programs. The aim should be to make these strategies sustainable.

In short, the role of logistics has changed but the aim is more or less still the same i.e. maintaining profitability. For achieving so, it becomes extremely essential for logistics organizations and businesses to embrace new technologies.

4.4 Service Processes

For any kind of organization, the basic role of service process is to improve client experience. Control and management of service process may lead to satisfied clients, more clients through referrals or even disappointments. Basically, service process is the way of offering services to customers. Two companies selling the same product can experience a huge difference in their revenues just due to the difference in the efficiency of service processes [49, 50]. As Industry 4.0 is more consumers centric, therefore, the role of service processes is experiencing a great change. Now, services are decided based on user needs. In the smart services era, all devices, machinery, remote factories are connected and digitalized. All services are represented in a virtual way on company platforms. In this way product, services or data can be accessed from anywhere. Marketplaces will also be completely automated in Industry 4.0 [40]. Factories and marketplaces can put requests to each other on digital platforms. For example, technologies such as big data or cloud can contribute in the development of systems which can combine human expertise and natural language processing. Using that data efficiency of machines can be improved. Also, it can provide better successor before an asset retires. More explained and suitable error messages can help improving overall designs. It has just begun to work automatically in service processes. This will need very intelligent algorithms which are able to choose the appropriate service and deliver. Full automation of service processes is difficult to achieve but once achieved then it has the potential to make a substantial impact on production and revenues.

5 Sustainability 4.0: UN'S Sustainable Development Goals in Industry 4.0

Two noteworthy issues stand up to the present reality. The first is about the Sustainable Development Goals (SDGs), set up by the United Nations, and the second is about the evolution in technology, prompting smart machines and without human-free industrialisation termed as Industry 4.0 or the fourth industrial revolution by the World Economic Forum [51].

From the global point of view, both of these are profoundly essential development issues. On one hand, we are confronting the challenge of delivering high yields from resources which are on the verge of depletion, while triggering less pollution and harm the earth for meeting ever growing consumption. Still, the development of Industry 4.0 is frequently causing the dread of employment issues and inequality [52]. While the studies find that Industry 4.0 has the potential to produce innovative ways to address global challenges, it cautions that its limits and its risks to sustainable development must be better understood.

Industry 4.0 is a blend of 10 key innovations: (1) Sensors, and Machine Intelligence Algorithms, (2) Autonomous Robots, (3) Big Data, Analytics, and Integration, (4) Simulation and Digital Twin, (5) The Industrial Internet of Things, (6) Cybersecurity, (7) The Cloud and Edge Computing, (8) Additive Manufacturing, (9) Augmented and Virtual Reality, and (10) Human-Machine Cooperation. Alternatively, sustainable development plan presents 17 noteworthy objectives of development with 169 targets shown in Fig. 12. The following subsections explore how technology portfolio

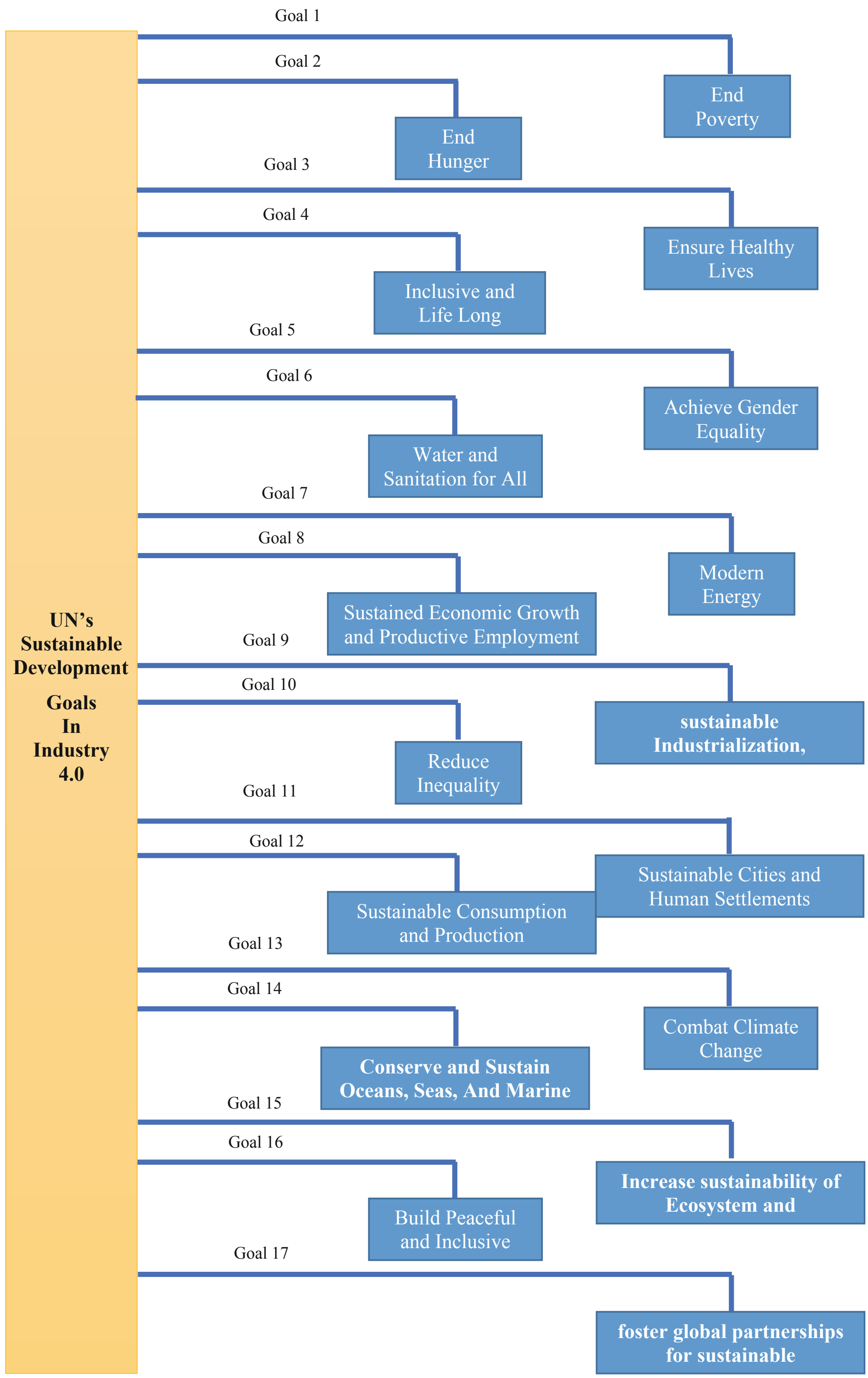


Fig. 12 Sustainable development goals in Industry 4.0

of Industry 4.0 could enable us to accomplish the 17 SDG and how the fourth industrial evolution addresses the problems of SDGs.

Goal 1—End Poverty As indicated by the latest reviews, in 2015, 10% of the total population of the world lived on below US$1.90 per day. In order to end poverty, increase in the income level of certain group is required which can be achieved through the sensors fitted in dairy and farming practices. In Asia and Africa, the dairy cows are tied with sensor fitted neck bands which include accelerometer with internet connectivity which is able to increase the frequency of recognizing when a cow is on heat and to guarantee it is provided with quality semen during Artificial Insemination (AI) [53]. Additionally, to expand the pay level of people associated in farming practices numerous beneficial applications could be developed around smartphone in order to educate them.

Goal 2—End Hunger As per The State of Food Security and Nutrition reports in World 2018, hunger has been on the ascent in the course of recent years, achieving 821 million in 2017 or one in each nine individuals. In one hand, arable land is diminishing, moreover, fertility of land, fresh water shortage, pesticide use, and other environmental concerns are growing. Technologies associated with the Industry 4.0 like drones, sensors, micro robotics, software, and data analytics could help farmers in producing more food utilizing the same farming area and making less wastage of raw materials and water. As per the pertinent studies yield could increment as high as 25% of increment in yield could be achieved simultaneously with the less wastage of inputs [54].

Goal 3—Ensure Healthy Lives Industry 4.0 technologies could be of huge help for the monitoring of health issues. The development of different wearable health monitoring machineries, smartphones and internet-connectivity-based devices could prompt huge improvement in varied areas whether it be maternal mortality or widespread access to health education and related information [55].

Goal 4—Lifelong Learning Rapid change in technologies leads to a rising issue of life-long learning. The rise of Virtual, and Augmented Reality (VR, AR) combined with internet-connectivity, smartphones, cloud computing, and distributed computing are opening chances to revolutionize in order to address this red-hot issue [56]. AR and VR could be of great help for improving industrial skills in developing countries further expanding production capacity. UNIDO has also found AR and VR based knowledge transfer solutions as inexpensive and operative devices to reduce poverty [57].

Goal 5—Achieve Gender Equality The issue of gender equality can be addressed by empowering girls and women with skills, education, and employment. Industry 4.0 opens the doors for facilitating skill development and furthermore contributing to remote employment. For instance, with the help of VR and AR gears, young ladies in remote villages of Bangladesh or India can offer supervision and help to individuals suffering from disabilities such as blindness. For instance, some business applications as of now give clients a couple of Google Glasses to blind individuals [58–60]. Connected over cellular network, Aira enables a remote operator to find continuously what the visually impaired client would see, and guide them in like manner.

Goal 6—Sanitation and Water for All The Industry 4.0 technology portfolio is pursuing smart water policy to open the chance to develop productive methods for decreasing water contamination and wastage. The term "smart water" represents water and wastewater infrastructure that guarantees this valuable asset is overseen viably [61]. A smart water framework is intended to accumulate exact, real time data about the stream, pressure, flow, and circulation of a city's water.

Goal 7—Modern Energy Beginning from energy efficiency improvement to creation of energy from wind and sun powered devices, and associating them to smart grid along with storage, various opportunities are there for the modern energy agenda to benefit from Industry 4.0 technology portfolio [62]. The maximum use of energy is observed by the industrial sector which accounts for 54% of the global delivered electricity. Naturally, factories and plants are consuming and wasting tons of energy so managing output and usage could have remarkable cost returns. This is where industrial IoT, or the Internet of Things, can have a major impact on the modern energy agenda. IoT sensors and IoT-empowered equipment can have the greatest effect if intended for savings [63, 64]. Moreover, Industry 4.0 offers the opportunity of profitable connectivity of renewable resources and intermittence management with storage.

Goal 8—Sustained Economic Growth and Productive Employment Industry 4.0 could be utilized by all nations, regardless of the development stage, to drive economic growth. For instance, with the systems like sensors, software, AI and 3D printing, wastage could be reduced, and emission could be brought down hence increasing the quality and reducing the expense [65]. Industry 4.0 additionally offers innovation center to drive businesses.

Goal 9—Sustainable Industrialization, Infrastructure and Innovation This is a complicated issue. Industry 4.0 is accused to be early industrialization in many developing countries. Research shows that over 50% industrial employment globally are vulnerable with the rising rushes of Industry 4.0. Developing countries are on the peak of risk [66]. Effectively growing number of jobs is being taken over by mechanical technology and automation. But the same technology portfolio additionally offers the chance of making new employments. The reconciliation of intelligence in production hardware and over the supply and distribution chain can possibly diminish wastage, pollution, and emission—making commitment to sustainable and reasonable industrialization through innovation [67].

Goal 10—Reduce Inequality So, far technology has been accused for growing inequality. Nevertheless, innovation has opened the door for many semi-skilled individuals to partake in industrial economy. During the most recent 50 years, technology has been the key reason for expansion of globalisation creating export-oriented manufacturing jobs in developing countries [68, 69]. Numerous advancements driving industry 4.0, for example, additive manufacturing, sensors, AI and software can possibly empower developing nations to foster innovation making their economies increasingly profitable [70]. It seems that Industry 4.0 has decreased the hindrance for developing nations to participate in development economy—allowing each nation to benefit by advanced technologies increasing the quality of life—in this manner diminishing disparity.

Goal 11—Make Cities and Human Settlement Sustainable Industrial age in the course of the last 300 years has made human settlements unsustainable, often unacceptable. Centralized production has urged individuals to join in little territories in making towns and urban communities, while disserting rural communities. Air, soil, and water pollution brought about by trade economy has made the environment of our cities toxic [71, 72]. The industry 4.0 offers is the opportunity to turn around the circumstance. It offers the chances to make urban areas liveable, and make gainful opportunities in rural communities. Rather than leaving rural areas, individuals will be able to certainly partake in beneficial events anyplace in the world in operating semiautonomous productive machinery by submerging in augmented reality environment.

Goal 12—Sustainable Consumption and Production Around 33% of the food produced in the for human utilization consistently (roughly 1.3 billion tonnes) gets lost or squandered as per the report of Food and Agricultural Origination of the UN. Food losses and waste adds up to approximately US$680 billion in industrialized nations and US$310 billion in developing nations. Food loss and waste likewise sum to a noteworthy wasting of assets, including energy, land, water, capital and labour and unnecessarily produce greenhouse gas emissions, adding to a dangerous atmospheric deviation such as global warming and climate change [73, 74]. The utilization of smart technologies in food harvesting, preservation, processing, and distribution can possibly lessen this wastage. Creating the market of innovation around sensors, smart vehicles, data analytics, and advanced robotics for reinforcing the production network, improving the prediction of demand in restaurants and hotels, grocery stores, and expanding food packaging industry could lessen the measure of food loss and waste.

Goal 13—Combat Climate Change Greenhouse gas emission from our productive activities is a noteworthy reason for an unnatural environment change and global warming. Ozone depleting substances trap warmth and make the planet hotter. Human exercises oversee the expansion in greenhouse gases in the air during the last 150 years. The biggest wellspring of ozone depleting substance outflows from human exercises is from consuming petroleum derivatives for power, heat, and transportation [75]. Technologies behind Industry 4.0 is opening the chance to power cars, trucks, ships, and trains with electric battery and hydrogen, significantly decreasing the emission from transportation. Advances are being made in making wind and solar as the fundamental sources of electrical energy. So also, when we succeed in making power created from sun and wind less expensive than fossil fuels, heating and every other type of demand will be met with clean energy. It gives the idea that rather than regulation, Industry 4.0 technology portfolio is opening the chance to strengthen completion in adopting clean production strategies to diminish emission and increment benefit at the same time.

Goal 14—Conserve and Sustain Oceans, Seas, and Marine Resources Decrease of contamination, dropping by- catch and controlling unapproved fishing activities can possibly save and sustain sea. In addition, innovation bolstered aquaculture has likewise the possibility to lessen the demand of fishing on vast ocean. Technologies like sensors, data analytics and augmented reality can possibly rise the accuracy of fishing further dropping bycatch [60]. Industry 4.0 innovation development additionally opens the way to lessen contamination and control unapproved fishing exercises.

Goal 15—Increase Sustainability of Ecosystem, and Biodiversity Data analytics and simulation devices are going to play a vital role to comprehend the possible consequences of change of biodiversity and ecosystem. On one side, such examination will give better insights to researchers to propose appropriate policy intervention. Then again, such instruments could be utilized to increment social attention to support the protection restoration and advancement of maintainable utilization of environment, land, and forests [57]. Additionally, innovation such as drones-based surveillance will likewise give real-time information to help the administration of woodlands, including ending deforestation, and expanding afforestation just as reforestation.

Goal 16—Build Peaceful and Inclusive Societies The fourth industrial evolution is made up of a set of ten technologies; many these could be utilized to address this critical agenda. Beginning from evidence gathering, to accelerate reasonable justices, developments and innovations in technology are playing an essential role [57]. The take-off of full potential of technologies in overseeing institutions will essentially improve transparency, and diminish bribery.

Goal 17—Foster Global Partnerships for Sustainable Development Although the fourth industrial revolution present risk to globalization of production, yet its innovation portfolio opens tremendous opportunity of development to sustainable growth of all countries [60]. Huge numbers of the worldwide issues like contamination, environmental change and migration could be addressed through participation among nations in expanding collaboration on and access to science, innovation and technology. Technology portfolio of Industry 4.0 gives off an impression of being very potential to help such participation through innovations in addressing issues for mutual benefits.

It can be observed that there is a solid relationship between Industry 4.0 technology portfolio and the objectives of sustainable development. The benefit derived from each country will depend on the approach being perused. For all nations, especially the developing countries, addressing the SDGs is crucial [76, 77]. In the absence of the adoption of advanced technologies, existing productive activities are not scalable to address most of the SDGs.

It can also be identified that the SDGs could provide guidance in realizing the economic and energy saving opportunities of interconnected manufacturing. It can be concluded that enhanced use of information and communication technologies could have a 'multiplier effect' yielding benefits for several SDGs, especially SDG 7 (Affordable and clean energy) and SDG 9 (Industry, innovation and infrastructure).

6 Conclusion

Industry 4.0 is a promising breakthrough in manufacturing that aims at unifying reality and the virtual world. It has the ability to push global manufacturing to an unforeseen level of optimization, productivity and efficiency and all this with added advantages of lower costs, better and flexible management, customization and automation. The only major challenges lie in the smooth transition of the current manufacturing and management processes to meet the demands of industry 4.0. A lot of research still needs to be done in the area. Infrastructure and skills need to be developed. With the integration of big data analytics, robotics, additive manufacturing, cloud services, IIoT to make the vision of smart products, smart manufacturing and smart factories become a reality, Industry 4.0 has lot to promise for the future.

References

1. H. Rauen, Industry 4.0 – The Technological Revolution Continues [Video], (2012) (Speaker) Retrieved January 12, 2016, from www.vdma.org/videoitem-display/videodetail/3019396www.vdma.org/video-item-display/-/videodetail/3019396
2. Götz, M., & Jankowska, B. (2017). Clusters and Industry 4.0–do they fit together?. European Planning Studies, 25(9), 1633-1653.
3. Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. Business & information systems engineering, 6(4), 239-242.
4. Bauernhansl, T., Ten Hompel, M., & Vogel-Heuser, B. (Eds.). (2014). Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung-Technologien-Migration (pp. 1-648). Wiesbaden: Springer Vieweg.
5. Brettel, M., Friederichsen, N., Keller, M., & Rosenberg, M. (2014). How virtualization, decentralization and network building change the manufacturing landscape: An Industry 4.0 Perspective. International journal of mechanical, industrial science and engineering, 8 (1), 37-44.
6. Kagermann, H., Wahlster, W., Helbig, J., Hellinger, A., & Karger, R. (2012). Im Fokus: das Zukunftsprojekt Industrie 4.0: Handlungsempfehlungen zur Umsetzung. Bericht der Promotorengruppe Kommunikation. Forschungsunion.
7. Industrial Internet Consortium, Industrial Internet Reference Architecture, Version 1.7, 2015.
8. Presentation at the French Embassy in the Germany, "Industry of the future", 2015. Available at. http://www.ambafrance-de.org/Vorstellung-des-neuen-franzosischen-Plans-Industrie-du-Futur-in-der-Botschaft. Last accessed: 24.11.2016
9. The State Council of the People's Republic of China, "Made in China 2025", Available at: http://english.gov.cn/2016special/madeinchina2025/. Last accessed: 24.11.2016.
10. Hermann, M., Pentek, T., & Otto, B. (2016, January). Design principles for industrie 4.0 scenarios. In 2016 49th Hawaii international conference on system sciences (HICSS) (pp. 3928-3937). IEEE.
11. Thomas Bauernhansl, Jörg Krüger, Gunther Reinhart, Günther Schuh: Wgp-Standpunkt Industrie4.0, Wissenschaftliche Gesellschaft für Produktionstechnik Wgp e. v., 2016.
12. Rojko, A. (2017). Industry 4.0 concept: background and overview. International Journal of Interactive Mobile Technologies (iJIM), 11 (5), 77-90.
13. Lee, H. Kao and S. Yang, "Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment", Procedia CIRP, vol. 16, pp. 3-8, 2014. Available: https://doi.org/10.1016/j.procir.2014.02.001.
14. K. Zhou, Taigang Liu and Lifeng Zhou, "Industry 4.0: Towards future industrial opportunities and challenges," *2015 12th*

International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), Zhangjiajie, 2015, pp. 2147-2152.
15. Gilchrist, A. (2016). Introducing Industry 4.0. In Industry 4.0 (pp. 195-215). Apress, Berkeley, CA.
16. Kumar, A., & Khorwal, R. (2017). Firefly algorithm for feature selection in sentiment analysis. In *Computational Intelligence in Data Mining* (pp. 693-703). Springer, Singapore.
17. Y, Lu, "Industry 4.0: A survey on technologies, applications and open research issues", Journal of Industrial Information Integration, vol. 6, pp. 1-10, 2017. Available: https://doi.org/10.1016/j.jii.2017.04.005.
18. Gilchrist, A. (2016). Industry 4.0: the industrial internet of things. Apress.
19. A. Gilchrist, "Middleware Industrial Internet of Things Platforms," in Industry 4.0, Springer, 2016, pp. 153-160.
20. B. Yan and G. Huang, "Supply chain information transmission based on RFID and internet of things," in 2009 ISECS International Colloquium on Computing, Communication, Control, and Management, 2009
21. R. Xu, L. Yang and S. H. Yang, "Architecture Design of Internet of Things in Logistics Management for Emergency Response," in Green Computing and Communications (GreenCom), 2013 IEEE and Internet of Things (iThings/CPSCom), IEEE International Conference on and IEEE Cyber, Physical and Social Computing, 2013.
22. B. Karakostas, "A DNS architecture for the internet of things: A case study in transport logistics," Procedia Computer Science, vol. 19, pp. 594-601, 2013.
23. Jain, D. K., Kumar, A., Sangwan, S. R., Nguyen, G. N., & Tiwari, P. (2019). A Particle Swarm Optimized Learning Model of Fault Classification in Web-Apps. *IEEE Access*, *7*, 18480-18489.
24. Gilchrist, A. (2016). Introducing Industry 4.0. In Industry 4.0 (pp. 195-215). Apress, Berkeley, CA.
25. Gorecky, D., Schmitt, M., Loskyll, M., & Zühlke, D. (2014, July). Human-machine-interaction in the industry 4.0 era. In Industrial Informatics (INDIN), 2014 12th IEEE International Conference on (pp. 289)
26. Kumar, A., & Jaiswal, A. (2019). Systematic literature review of sentiment analysis on Twitter using soft computing techniques. *Concurrency and Computation: Practice and Experience*, e5107.
27. R. Drath, A. Horch, Industrie 4.0: Hit or Hype? [Industry Forum]. Industrial Electronics Magazine, IEEE 8 (2014) 56-58.
28. Alzubi, J., Nayyar, A., & Kumar, A. (2018, November). Machine learning from theory to algorithms: an overview. In *Journal of Physics: Conference Series* (Vol. 1142, No. 1, p. 012012). IOP Publishing.
29. Kumar, A., & Sangwan, S. R. (2019). Rumor Detection Using Machine Learning Techniques on Social Media. In *International Conference on Innovative Computing and Communications* (pp. 213-221). Springer, Singapore.
30. M. Ford, Industry 4.0: Who Benefits? SMT: Surface Mount Technology 30 (2015) 52-55.
31. R. Schmidt, M. Möhring, R.-C. Härting, C. Reichstein, P. Neumaier, P. Jozinović, Industry 4.0 - Potentials for Creating Smart Products: Empirical Research Results, in: W. Abramowicz (Ed.), Business.
32. C.a.R. Hilger, J, Auto-ID integration-a bridge between worlds. German Harting Magazine (2013) 14-15.
33. H. Lasi, P. Fettke, H.-g. Kemper, T. Feld, M. Hoffmann, Industry 4.0. Business & Information Systems Engineering 6 (2014) 239-242.
34. J. A. Simpson, E.S. C. Weiner, and Oxford University Press, Eds., The Oxford English dictionary, 2nd ed. Oxford: Oxford; New York: Clar-endon Press; Oxford University Press, 1989.
35. Bhatia, M. P. S., & Kumar, A. (2010). Paradigm shifts: from pre-web information systems to recent web-based contextual information retrieval. *Webology*, *7*(1), 1.
36. M. Kohlegger, R. Maier, and S. Thalmann, "Understanding Maturity Models Results of a structured Content Analysis," presented at the I-KNOW '09 and I-SEMANTICS '09, Graz, Austria, 2009.
37. Industry 4.0: Definition, Design Principles, Challenges, and the Future of Employment, https://www.cleverism.com/industry-4-0/.
38. https://www.forbes.com/sites/bernardmarr/2018/09/02/what-is-industry-4-0-heres-a-super-easy-explanation-for-anyone/#8105a7e9788a
39. Geissbauer R, Vedso J, Schrauf S (2016) Industry 4.0: Building the digital enterprise. Retrieved from PwC Website: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/ industry-4.0-building-your-digital-enterprise-april-2016.pdf.
40. Gilchrist, A. (2016). Industry 4.0: the industrial internet of things. Apress.
41. Almada-Lobo, F. (2016). The Industry 4.0 revolution and the future of manufacturing execution systems (MES). Journal of innovation management, 3(4), 16-21.
42. Bhatia, M. P. S., & Khalid, A. K. (2007, November). Contextual proximity based term-weighting for improved web information retrieval. In *International Conference on Knowledge Science, Engineering and Management* (pp. 267-278). Springer, Berlin, Heidelberg.
43. Schumacher, A., Erol, S., & Sihn, W. (2016). A maturity model for assessing industry 4.0 readiness and maturity of manufacturing enterprises. Procedia CIRP, 52, 161-166.
44. Kumar, A., & Goel, R. (2012, March). Event driven test case selection for regression testing web applications. In *IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM-2012)* (pp. 121-127). IEEE.
45. K. Lichtblau, V. Stich, R. Bertenrath, M. Blum, M. Bleider, A. Millack, K. Schmitt, E. Schmitz, and M. Schröter, "IMPULS - Industrie 4.0-Readiness," Impuls-Stiftung des VDMA, Aachen-Köln, 2015.
46. Rockwell Automation. (2016). The Connected Enterprise Maturity Model. Retrieved from Website:http://literature.rockwellautomation.com/idc/groups/literature/documents/wp/ciewp002_-en-p.pdf.
47. IMPULS-Industrie 4.0-Readiness. Impuls-Stiftung des VDMA, Aachen-Köln.
48. A. Sharma, R. Ranjan, "Software Effort Estimation using Neuro Fuzzy Inference System: Past and Present" published in International Journal on Recent Innovation Trends in Computing and Communication (IJRITCC), ISSN: 2321-8169, Vol.5, Issue.8, Pp: 78-83.
49. Schumacher A, Erol S, Sihn W (2016) A maturity model for assessing industry 4.0 readiness and maturity of manufacturing enterprises. Procedia CIRP 52:161–166.
50. http://www.apics.org/apics-for-individuals/apics-magazine-home/magazine-detail-page/2017/09/20/industry-1.0-to-4.0-the-evolution-of-smart-factories
51. Kumar, A., & Joshi, A. (2017, March). SentIndiGov-O: an Ontology-based Tool for Sentiment Analysis to Empower Digital Governance. In *Proceedings of the 10th International Conference on Theory and Practice of Electronic Governance*(pp. 576-577). ACM.
52. Kumar, A., & Sharma, A. (2013). Alleviating sparsity and scalability issues in collaborative filtering based recommender systems. In *Proceedings of the International Conference on Frontiers of Intelligent Computing: Theory and Applications (FICTA)* (pp. 103-112). Springer, Berlin, Heidelberg.

53. Batth, R. S., Nayyar, A., & Nagpal, A. (2018, August). Internet of Robotic Things: Driving Intelligent Robotics of Future-Concept, Architecture, Applications and Technologies. In *2018 4th International Conference on Computing Sciences (ICCS)*(pp. 151-160). IEEE.
54. Nayyar, A., Puri, V., & Le, D. N. (2017). Internet of nano things (IoNT): Next evolutionary step in nanotechnology. *Nanoscience and Nanotechnology*, *7*(1), 4-8
55. Nayyar, A., Jain, R., Mahapatra, B., & Singh, A. (2019). Cyber Security Challenges for Smart Cities. In *Driving the Development, Management, and Sustainability of Cognitive Cities* (pp. 27-54). IGI Global.
56. Gorecky, D., Schmitt, M., Loskyll, M., & Zühlke, D. (2014, July). Human-machine-interaction in the industry 4.0 era. In Industrial Informatics (INDIN), 2014 12th IEEE International Conference on (pp. 289-294). IEEE.
57. Robert, K. W., Parris, T. M., & Leiserowitz, A. A. (2005). What is sustainable development? Goals, indicators, values, and practice. *Environment: science and policy for sustainable development*, *47* (3), 8-21.
58. Labuschagne, C., Brent, A. C., & Van Erck, R. P. (2005). Assessing the sustainability performances of industries. *Journal of cleaner production*, *13*(4), 373-385.
59. Kumar, A., Sharma, A., Sharma, S., & Kashyap, S. (2017, July). Performance analysis of keyword extraction algorithms assessing extractive text summarization. In *2017 International Conference on Computer, Communications and Electronics (Comptelix)* (pp. 408-414). IEEE.
60. Rokon Zaman, Industry 4.0 Drives the Sustainable Development Goals, Waves, https://techpolicyviews.com/review-updates/2018/11/18/industry-4-0-drives-the-sustainable-development-goals/
61. Kumar, A., & Bhatia, M. P. S. (2012). Community expert based recommendation for solving first rater problem. *International Journal of Computer Applications*, *37*(10), 7-13.
62. Lukman, R. K., Glavič, P., Carpenter, A., & Virtič, P. (2016). Sustainable consumption and production–Research, experience, and development–The Europe we want. *Journal of cleaner production*, *138*, 139-147.
63. Kumar, A., & Joshi, A. (2017, March). Ontology driven sentiment analysis on social web for government intelligence. In *Proceedings of the Special Collection on eGovernment Innovations in India* (pp. 134-139). ACM.
64. Das, S., & Nayyar, A. (2019). Innovative Ideas to Manage Urban Traffic Congestion in Cognitive Cities. In *Driving the Development, Management, and Sustainability of Cognitive Cities* (pp. 139-162). IGI Global.
65. Ranjan, R., & Sharma, A. (2019). Evaluation of Frequent Itemset Mining Platforms using Apriori and FP-Growth Algorithm. *arXiv preprint arXiv:1902.10999e*.
66. Kumar, A., & Sebastian, T. M. (2012). Machine learning assisted sentiment analysis. In *Proceedings of International Conference on Computer Science & Engineering (ICCSE'2012)* (pp. 123-130).
67. Kumar, A., Khorwal, R., & Chaudhary, S. (2016). A survey on sentiment analysis using swarm intelligence. *Indian J Sci Technol*, *9*(39), 1-7.
68. Singh, S. P., Nayyar, A., Kaur, H., & Singla, A. (2019). Dynamic Task Scheduling using Balanced VM Allocation Policy for Fog Computing Platforms. *Scalable Computing: Practice and Experience*, *20*(2), 433-456.
69. Singh, S. P., Nayyar, A., Kumar, R., & Sharma, A. (2019). Fog computing: from architecture to edge computing and big data processing. *The Journal of Supercomputing*, *75*(4), 2070-2105.
70. Solanki, A., & Nayyar, A. (2019). Green Internet of Things (G-IoT): ICT Technologies, Principles, Applications, Projects, and Challenges. In *Handbook of Research on Big Data and the IoT* (pp. 379-405). IGI Global.
71. Bhatia, M. P. S., & Kumar, A. (2009). Contextual paradigm for ad hoc retrieval of user-centric web data. *IET software*, *3*(4), 264-275.
72. Kumar, A., Sharma, A., & Arora, A. (2019). Anxious Depression Prediction in Real-time Social Data. *arXiv preprint arXiv:1903.10222*.
73. Kumar, A., & Sharma, A. (2017). Systematic literature review on opinion mining of big data for government intelligence. *Webology*, *14*(2), 6-47
74. Singh, P., Gupta, P., Jyoti, K., & Nayyar, A. (2019). Research on Auto-Scaling of Web Applications in Cloud: Survey, Trends and Future Directions. *Scalable Computing: Practice and Experience*, *20*(2), 399-432.
75. Kaur, A., Gupta, P., Singh, M., & Nayyar, A. (2019). Data Placement in Era of Cloud Computing: a Survey, Taxonomy and Open Research Issues. *Scalable Computing: Practice and Experience*, *20* (2), 377-398.
76. Kumar, A., & Ahmad, N. (2012). ComEx miner: Expert mining in virtual communities. *International Journal of Advanced Computer Science and Applications (IJACSA)*, *3*(6).
77. Kumar, A., & Sharma, A. (2019). (1706-3727) SYSTEMATIC LITERATURE REVIEW OF FUZZY LOGIC BASED TEXT SUMMARIZATION. *Iranian Journal of Fuzzy Systems*.

Akshi Kumar is an Assistant Professor in the Department of Computer Science and Engineering at Delhi Technological University (formerly Delhi College of Engineering). She has been with the university for the past 10 years. She has received her Ph.D. in Computer Engineering from Faculty of Technology, University of Delhi in 2011. She completed her Master of Technology with honours in Computer Science and Engineering from Guru Gobind Singh Indraprastha University, Delhi in 2005. She received her Bachelor of Engineering degree with distinction in Computer Science and Engineering from Maharishi Dayanand University, India in 2003. She has presented several papers in international conferences and published work in peer-reviewed and science cited journals. Dr. Kumar has also authored a book 'Web Technology: Theory and Practice' published by CRC Press, Taylor and Francis Group. She is active reviewer of many top journals of IEEE, IET, Springer, Emerald and Elsevier. In addition, she is currently serving as a Guest Editor of Springer Energy Systems. Her research interests are in the area of intelligent systems, user-generated big-data, social media analytics and soft computing.

Anand Nayyar received the M.C.A. degree from Punjabi University, Patiala, in 2008, the M. Phil. degree in computer science with the 1st Division from Vinayaka Missions University, in 2009, the M.Tech. degree (Hons.) in information technology in 2011, the M.B.A. degree in information systems from Sikkim Manipal University with 1st Division, and the Ph.D. degree in computer science from Desh Bhagat University, Mandi Gobindgarh, in 2017. He is currently working with the Graduate School, Duy Tan University, Da Nang, Vietnam. He has more than 300 Publications in various National, International Conferences cum International Journals (Scopus/ISI/SCI/SCIe) of high repute. He is currently in WSN, MANET, swarm intelligence, cloud computing, big data, network security, the Internet of Things (IoT), machine learning, deep learning, network simulation, and 5G communications. He is the acting Editor-in-Chief for journal titled "International Journal of Smart Vehicles and Smart Transportation (IJSVST)".

Development of Industry 4.0

Aditi Sharma and Deepak Kumar Jain

Abstract

With the upsurge of technology inventions, the manufacturing industries has revolutionized. Industrial revolution has completely transformed the social and economic life of an individual. It started in the seventeenth century with the use of simple steam engines has come a long way. Every major breakthrough in the technology changed the face of manufacturing industries. At present, we are in the era of Industry 4.0 which is hailed as the age of cyber-physical systems that has taken manufacturing and associated industry processes to an unforeseen level with flexible production including manufacturing, supply chain, delivery, and maintenance. This chapter presents an in-depth discussion on various aspects of Industry 4.0, its beginning, the founding pillars of industry 4.0. In addition to that other allied rudiments such as cross-technological, functional, talent and business developments are also discussed from the perspective of real time scenarios. This chapter also previews detailed knowledge about horizontal-vertical system integration and supply chain that aids in enabling and designing smooth manufacturing process in order to gain more profit.

Keywords

Industrial evolution · Industry 4.0 · IOT · Smart factories · Talent · Technology and business development in Industry 4.0 · Supply chain · Horizontal and vertical integration

A. Sharma (✉)
DIT University, Dehradun, India

D. K. Jain
Chongqing University of Posts and Telecommunications, Chongqing, China
e-mail: deepak@cqupt.edu.cn

1 Introduction

With the advancement of technology, every field whether it is Medical, Governance, Entertainment, Commerce, are embracing the change of technology to ensure continuous improvement. Same is being pertained by the manufacturing industries. The development process in industries has always been in pace with the technology of the time. With the invention of steam engines in the seventeenth century lead to the change the process of manufacturing in eighteenth century in Britain by using the basic materials like iron and steel using motive power (Steam engine) and fuels (Coal, Petroleum) as the energy sources lead to new beginning of manufacturing process. This was known as the first Industrial Revolution or Industry 1.0. It changed the way how we used our human resources, they needed to be skilled to work efficiently in the new industries. Due to the use of the technology, mass production in less time became possible and lead to the increase in international trade.

At the end of the nineteenth century, with the invention electricity started the second industrial revolution. It's also known with the name of technological revolution, as it set the footprints for various technologies. It was during the time of second revolution, that railroads, paper making, synthetic dye, petroleum refining industry, all developed rapidly [1]. Second revolution used the machine tools from the first revolution and started manufacturing in parts. It even more distributed the human labors into specified tasks. This division of labor increased the productivity. This revolution lost its charm with the first world war in early twentieth century.

The third industrial revolution was inspired by the innovations in the electrical engineering. As it was inspired from the digital electronics, it is also known as the Digital Revolution. In the late twentieth century, with the invent of digital computers, internet the industries changed the way the processed the products. The industries we see in this present era or as we say in this information age are the children of

A. Nayyar, A. Kumar (eds.), *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-14544-6_2

third industrial revolution. It makes the production system fast and manageable.

To create the exact replica of a product became the easiest task [2]. It not only changed the manufacturing process but also brought innovations to the business and marketing of the products. The work of the machines in these industries are so fascinating that a special TV show with the name Food Factory started in 2012 in Canada and became popular across all the nations. Industry 3.0 is a product of information age, but it still needs human help to complete the product and the digital logical machines has only impacted how we manufacture the product not how the whole process is being carried out [3]. So, the need for forth revolution of industry has emerged. It is still in its conceptual phase, but Germany has implemented some of the industry 4.0 principles in few industries.

Industry 4.0 or the fourth industrial revolution is a revolution which will change how we look at the development process, it is not just easing the process it is changing our life too. The revolutions till now has improved the working efficiency of the machines and lead to the mass production, this evolution of industries is shown in Fig. 1 [4]. Industry 4.0 uses the concept of Cyber Physical Systems (CPS), Cloud Computing and the Internet of Technologies (IoT) [5]. In this revolution, the machines are provided with artificial intelligence and the raw products are embedded with the RAID chips, which correlates the product with the development process. It will not just impact the industries but will impact economics too. Let's first formally describe the Industry 4.0 and its components, then we will discuss it in detail.

1.1 Industry 4.0

As it is still in the early phase, industry 4.0 is described by different communities in different terms, like medical field believes it is the way we can transforms the human living, while government believes it is a way to enhance the economics and so on [6]. We are here taking a few of the definitions which bring different perspective of the communities.

> Industry 4.0 is a collective term for technologies and concepts of value-chain organizations. Within the modular structured smart factories of Industry 4.0, CPS monitor physical process, create a virtual copy of the physical world and makes decentralized decisions. Over the IoT, CPS communicates and cooperates with each other and humans in real time. Via, the IoS, both internal and cross-organizational services are offered and utilized by participants of the value chain. [1]

"*Industry 4.0 aims for optimization of value chains by implementing an autonomously controlled and dynamic*

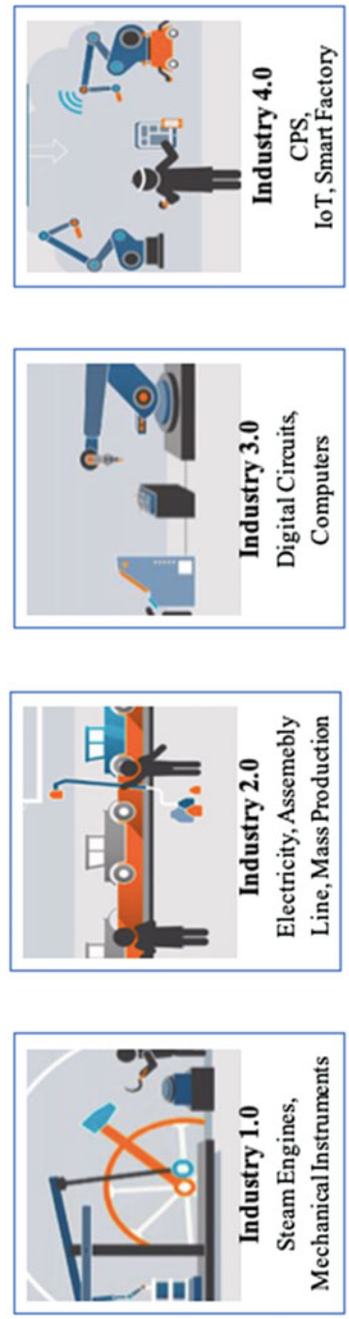


Fig. 1 Evolution of industry

production." is a definition given by three German researchers [7].

As stated by PWC [8], "*While Industry 3.0 was focusing on the automation of single machines and process, industry 4.0 focuses on the end-to-end digitization of all physical assets and integration into digital ecosystems with value chain partners.*"

Industry 4.0 is the term used to indicate how we want our future manufacturing industries to be, the first most critical component of this future endeavor is CPS [9]. Cyber physical system is the concept of embedding software in a physical thing, meaning a manufacturing machine with the software to understand itself. CPS will generate the smart machines which will have the ability to manage themselves, can report that they need servicing, or some updation to meet the continuous evolution of the product, and if possible can do some of self-maintenance work itself [10]. These manufacturing devices will have the knowledge about their own capabilities, like how much quantity they can process in a second, and after what manufacturing process they will have to start the work, and they can keep the count of the products processed by them [11].

Next foundation of industry 4.0 is IoT and IoS, where the internet which is already being used in industry 3.0, works in collaboration with embedded software, through this internet connectivity in all the digital circuits, we can control and link different types of products. The basic example of IoT is to control our home appliances using our phone, even when not in home. This very technology and the services provided by it (IoS) enables to connect machine with the products. And the factory where these smart machines operate is known as smart factory which we will discuss in detail in next section.

CPS, Smart Factory and IoT, IoS are the foundations of Industry 4.0 [12]. The technology due to which the fourth industrial revolution is possible is shown in Fig. 2. Without these technologies, industry 4.0 is just a dream, it is because of the advancement in robotics that now we don't need humans to do labor work, and the miniaturization of RFID made possible to build a connection between raw products and the machines. Similarly, without any of these technologies, Industry 4.0 cannot become a reality, that's why they are known as the technological pillars of Industry 4.0.

Apart from these technological pillars [13–16], industry 4.0 have four design principles as Interconnection, Information transparency, technical assistance and Decentralized decisions [17]. These principles ensure that every manufacturing process should be with the developed with the connected devices, people and machines and every decision taken by the machines or humans should be transparent with urgent works done with priority with the assistance of other connected devices if needed. The last design principle is to be able to take decisions at own level, rather than waiting for a central machine's or human in charge's order.

Industry 4.0 is capable of developing highly customizable products and at the same time can do the mass production, but with every great invention comes some problem. Some of the major challenging factors for the fourth revolution are security, employment, Capital and Privacy [4]. As fascinating it is to have a high-quality products for consumers, and high revenues for business people and demand of software for IT industries, yet the labors currently working in the industries will not be needed if not all, then most of them will have to face the unemployment. Although, it is difficult to estimate the future employment for those, however the need for skilled software developers will rise with it. The talent and technology development factor will be discussed in the Sects. 2 and 3 respectively, and the development of business will be discussed in Sect. 4. Next section discusses the Vertical and horizontal integration in the fourth revolution. Last section completes the framework of Industry 4.0 by discussing the end to end process i.e. Smart Supply Chain.

2 Smart Factories

Smart factory is the heart of industry 4.0. The whole concept of new revolution business, product, machines, sales are either part of or depends on the smart factory. Smart factories have large control over themselves and are able to optimize themselves too. In Martin's words "The Smart Factory can be defined as a factory where CPS communicate over the IoT and assist people and machines in the execution of their tasks" [4]. In simple terms a smart factory is a factory where smart machines work to produce smart products. In future, the smart factories will not only be able to manufacture, but will deliver the product too. As the communication between machine and product and the trucks or other devices which will carry the products for delivery will be interconnected by the CPS and will communicate through the IoT, they all are used inside Smart Factory.

Machines and materials are the assets that are located at the bottom line of the whole automation pyramid but are all well integrated through standardized interfaces. Materials and products are uniquely identifiable and locatable at all times during the manufacturing process and as well along their entire life-cycle. These smart materials and products are customized to a large extent at the costs of mass production [18]. The department of Innovative Factory Systems (IFS) at the German Research Centre for Artificial Intelligence (DFKI) identified four enablers for the Smart Factory: Smart Products know their production process and negotiate it with Smart Machines. The Smart Planner optimizes processes in nearly real time. In this environment, humans take a central position. Supported by innovative ICT they become Smart Operators who supervise and control ongoing activities [7].

Fig. 2 Technological pillars of Industry 4.0

Let us understand the working of a smart factory and its need with an example. Consider a company which manufactures the yogurt, in the current era at least 15 different flavours of yogurt exist. The process of making the yogurt for each fruit flavour is same, first the jam is made from the fruit and at the same time in different container the process of making the yogurt start, and when both the products are ready they are put into the flavoured labelled containers by combining in the certain ratio, and the container is sealed and dispatched for the sales [19]. This process seems problem-free but, if by human mistake the wrong flavour is mixed into the yogurt and it is contained with different label, a possible mistake as to err is a human. This scenario exists because the machine has no intelligence. Now look at the other perspective, if a company is manufacturing say five fruit flavoured yogurt, then if it has only one machine which is pouring the yogurt and flavour into the container, then at a single time only one flavoured yogurts will be manufactured, and if they have five different machines, so at each conveyer belt different flavoured yogurt is developed, the company is able to meet the demands, and produce more products in less time, but at a five times cost, while every machine is doing the same work, just adding the different flavour, they had to purchase five times the machine they actually needed. Due to season, one of the fruits is not available then either that machine is idle, or the company will use it for the manufacturing the other yogurt, which will double the supply irrespective of the need of that particular product in the market.

Industry 4.0's Smart factory has intelligent machines (CPS) and the products enabled with the RFID chip and they are interconnected through the IoT. Now if same five fruit flavoured yogurts are to be manufactured in a smart factory, the scenario will completely change. As the yogurt cup will have RFID chip they will have the information which product (flavoured yogurt) will be filled in it and at the same time, every machinery will have artificial intelligence and can perform machine to machine (M2M) communication. Every container will have the information which raw product it contains, which flavoured jam, Low fat milk, or high fat milk yogurt, So while even having a single machine to mix the yogurt and flavour, machine will know that for the particular cup on the conveyor belt which two products should be poured into. It not just remove the chance of error of having different flavour in different labelled cup, will also optimize the process, as machines has the intelligence and the

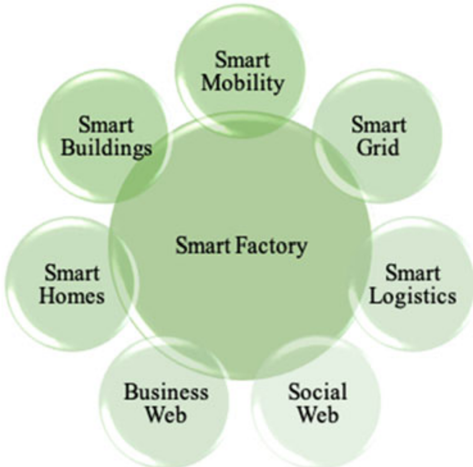


Fig. 3 Smart factory components

information is transparent in a smart factory, they have the information which product is in more demand and can accordingly more manufacture that flavour. And rather than going to all the yogurt first in warehouse and them supplied to different distributers, the packaging machine will pack the combinations of different flavours in one cart as per the requirement of the distributor, and directly send to the distributor. Smart factory doesn't only handle the manufacturing and delivery, it will also be possible through the RFID chip in yogurt cup when it has been used, so it will help the company to analyse the demands. Figure 3 represents all the components that constitute the Smart factory.

The other important feature provided by industry 4.0 is the customization of the products. It will be fulfilled by the Smart factories, if a customer demands a yogurt which is mix of two fruit flavours say mango and strawberry, now this detail will just need to be fed in the yogurt cup's RFID chip, and the machine will know that in this particular cup they have to pour content from three containers. RFID chip can be configured in multiple ways depending upon the product, it can be helpful for the customer too. After receiving the product customer can send the box's bar code number to the organization through mobile SMS, and company can then map the RFID with the mobile number, in this way as the RFID has all the information stored, it can alert the owner of the box on his/her phone that expiry date of the yogurt is near and it should be consumed. As sales is also interlinked to the smart factory, a consumer can also place the order through their phones, and can request for customization too.

As we discussed in the start of this section that smart factories are the heart of the industry 4.0, is because every other building block of manufacturing industry revolves around the smart factory. In traditional days, a factory's work was to produce the product with the help of the machines for which the raw product came from the store, and after the manufacturing it is handed over to the distributor team by sending it to the warehouse, from where products are sent to different cities and then to the stores. In smart factory every aspect of this is connected, even when the raw products arrive at the store, due to IoT in the store, the machines are informed that new material is coming, If the machines already have the material and don't need new raw products, they can command to stop loading more raw contents in to the container, and when they need it they can request for it. Like in the case of Yogurt industry, as to make the yogurt, milk need to be pasteurize, and a yogurt should not be kept in open for too long to avoid making it acidic. So when the machine notices that the yogurt available in the container to fill the cups will be finished in next 10 h in case of high-fat yogurt and 18 h in case of fat-free yogurt, it will instruct the milk machine to prepare the respective yogurt. This ability to take decision or to request and to command to other machines is the decentralized approach of the industry 4.0.

Smart factories because of the linkage, they know which order needs to be delivered first, so they can prioritize the tasks as per as shown in Fig. 4. This will ensure the timely delivery of the products. Smart factories are not just a conceptual concept, many companies started following this approach too, like Airbus the aircraft manufacturing industry

Fig. 4 Smart factory

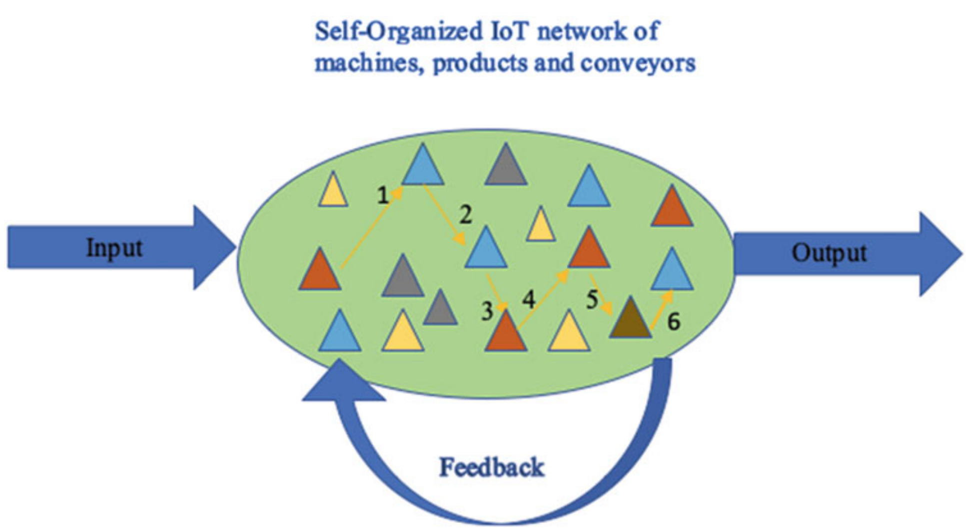


Table 1 Architecture layers of Industry 4.0

Layer	Functionality
Physical resource layer	• Collection of smart machines, smart products, smart conveyors • This is the fundamental layer and all its resources communicate through industrial network layer
Industrial network layer	• It acts as a bridge between physical resource layer and cloud layer • It enables communication between smart machines, products and other physical resources
Cloud layer	• The data generated from different physical layer resources are kept on the cloud through internet, as on the large-scale industries big data is generated, cloud meets the demand for storage • With IaaS, PaaS, and SaaS, it provides not just storage but also provides processing capabilities
Supervision and control terminal layer	• Provides connectivity between consumers and the smart factory • Helps in maintenance

is working with National instruments to augment their current factory to smart factory for the dropping in the faults occurring in manufacturing process. China is also proposing to build smart factories under its project "Made in China-2025", where they are proposing to build the new factories following the principle of industry 4.0. It's a 10 year proposed by China in 2015 to launch an industrial transformation from labour intensive production to knowledge intensive manufacturing [20].

As classified by Wang et al in [21] Smart factory has four basic layers in its system architecture each performing different tasks as shown in the Table 1. It is with the combination of all the technological pillars of the industry 4.0 that a successful smart factory can be build.

Smart industries will have smart operators as humans, but the number of humans needed in the factory will reduce tremendously [22], and will be replaced by the technology driven machines and software. The development of these technology and talent of humans is discussed next.

3 Technology Development in Industry 4.0

Industry 4.0 also commonly called as the 'Fourth Industrial Revolution' abridges future industrial developments mania for achieving more intelligent technological aspects of Industry 4.0 by combining several major technical innovations that is expected to drift the landscape of the manufacturing industries.

The crucial aspect of Industry 4.0 is to make the manufacturing process fast, forward, efficient, reliable, and customer oriented in order to discover novel business opportunities and models [23]. The pyramid model as shown in Fig. 5 clearly briefs about the varied aspects of Industry 4.0.

Fig. 5 Key objectives of Industry 4.0

This fourth Industrial Revolution is primarily driven by humongous volumes of data, computing power and connectivity. It majorly centers on the digitization of the manufacturing process [24]. Business markets are ever expanding these days via e-commerce which is minimizing the communication between the manufactures and the consumers. Customers, nowadays, are more center-staged and demand customized and personalized products which are further appending to the increasing challenge for the manufacturing sector. All this has consequently necessitated the need to manufacture the smart industries that include smart services as well [25].

Following this global trend and based on the wide-open innovation platforms, technology development is needed and is viable for achieving the objectives of Industry 4.0. We can also say that the automation of the production is required at a faster pace. Hence, a new paradigm of data-centric industrial revolution entails a deeper transformation based on the intel-

Fig. 6 Technology developments in Industry 4.0

Table 2 Key objectives of Industry 4.0

Technologies	Description
IIOT	Industrial Internet of things (IIOT) is associated with the concept of virtual world. Industry 4.0 look forward to increasing use of Internet and IOT for achieving enhanced human-machine interactions that could further enable intelligent manufacturing, thus aiding the fourth industrial revolution. Blending of the physical world with the virtual world has been made possible with the help of technological innovations in the field of IOT [27] that could possibly accomplish things talking to each other. It includes laser scanners, global positioning systems, sensors etc.
Cyber physical system	Cyber physical or cyber physical production systems (CPS) are the ones that connect with the real physical world [26]. CPS together with the IOT is often used for merging the physical world with the virtual world. Together, they aim to accomplish the production of more intelligent smart factories which could further lead to enhanced and smart production thus enabling faster and efficient digitations. The emergence and development of CPS technology will promote open-ended industrial innovations [23, 27–29] including energy production, transport, logistics, machinery, heavy industry, iron, steel metallurgy etc.
Cloud computing	It has emerged as a computing paradigm that imparts varied Internet services in a high cost efficient manner [23, 26, 27] to the users. These are quite compatible for dynamic memory allocation and resource sharing etc. Hence, enabling users to use the cloud resources as per their needs including hardware, software, infrastructure resources etc.
Agility and sequencing	It is a method of manufacturing that encapsulates the sequencing mechanism [23, 26, 27] where for any specific configuration, its parts arrive at a production line at the apt time as per customer-centric configuration details. It is quite analogous to just-in-time sequencing methodology
Additive manufacturing	This often includes 3D printing etc. that are used for production of individual components. With the augment of Industry 4.0, this technology would gain fruitful impact and boost the production of customized and personalized products [23, 26, 27] by the manufacturers
Big data, data mining and data analytics	Big data is the new buzzing term often used these days. Big data technology is used for gaining proper insight in order to fetch relevant information from heterogeneous and un-structured online available Web data. Utilizing the advantages of big data, together with the data mining techniques and data analytics, can serve as a boom for better analyzing the data and eventually aid in the production process. Proper collision of these technologies would promote benefits to manufacturing companies including optimizing the process, cost reduction and provides improvement in the operational processing [23, 26, 27]
Artificial intelligence	Artificial intelligence is a science [23, 26, 27] that deals with the adaptive and collective intelligence for extracting valuable gamut of real time information as and when needed using efficient tools and technologies including machine learning, population based heuristic algorithms, deep learning etc.
Cobot	It is commonly called as collaborative robotics (Cobot). It belongs to a new generation of robotics [23, 26, 27] that work in a very cooperative manner with the humans without requiring any security restrictions etc. These are programmed for better accessibility flexibility and ease of use
Augmented reality	Different variety of services including selection of parts in warehouse, conveying instructions related to repair of the mobile devices etc. are provided with the help of augmented reality based systems [23, 26, 27]. They aim to furnish the real time information that could be used by workers etc. for effective and efficient decision making procedures
CAD/CAM	It is often called as computer aided design and manufacturing [23, 26, 27]
MES/SCADA	It is called as manufacturing execution systems/supervisory control and data acquisition. It entails the shop floor monitoring with real time data collected by using SCADA and remote control of production, transforming long-term scheduling in short term orders with MES [23, 26, 27]
Sensoring	It involves the use of cognitive capabilities like sensing, decision making and reasoning used in making robots etc. [23, 26, 27]
On demand manufacturing	These days, markets are customer-centric. In order to stay competitive and worthwhile, manufactures/companies ought to act accordingly as per the customer's rapidly changing needs. All this is creating a variable and viable demand pattern in the upcoming manufacturing technology [23, 26, 27]. The manufactures are thus, required to manufacture the stuff as demanded by the customer, relying together with the agility and sequencing

ligent integration of various technological developments. These essential technologies [26] that pave the way for the Industry 4.0 transition are shown in Fig. 6. The detailed descriptions about these advances are specified in Table 2.

Proper channelization and utilization of the technologies given in Table 2 can further promote several benefits for the digital industry. The open-ended integration of these technologies would aid in further growth of the digitization of the industries [30–34] and help achieve the objectives of this fourth industrial revolution. Achieving Industry 4.0 is not a game. It is like a mission for our practitioners, academicians, industrialist etc. Currently, Industry 4.0 is a sort of futuristic vision [28, 29, 35–38] for us as it envisages different aspects, challenges such as scientific, political, social, technological and economic challenges.

4 Talent Development in Industry 4.0

Industry 4.0 is an era of data i.e. it encapsulates humongous amount of data and processed data i.e. information available on Web. The fourth industrial revolution deals with the emergence of this huge data and expansion of the connected systems. This self-adaptive, intelligent and real time based connected systems serve as the prime factors for accomplishing the goal of Industry 4.0. They act as the backbone of ever changing, dynamic and revolutionizing technology. Furthermore, this revolution will cogently be the driving factor for any novel business also. Industry 4.0 is actively transforming the dynamics of the industries. The emergence of huge amount of data and new automated business models is eventually creating a need for a talented and skillful workforce. All this in actuality requires possession of right talent in order to fulfill the goals. Hence, talent development in industry 4.0 is indispensable. It entails capturing new talents plus remodeling and re-designing the existing talents according to the changing needs of the industry.

With the proliferation of Web 2.0 tools and technologies, data is shared on real time basis. This dynamic exchange of real time information among the humans, systems and the materials [36, 37] is propelling the need of additional autonomous production systems and techniques to manufacture them. This is seriously affecting the overall dynamism of the industries these days.

Talent Development: Two Sides of a Coin Upcoming novel areas such as data sciences, bio-economics, cloud computing etc. demands the formation of novel business models pertaining to the relevant field. Additionally, advancements in the fields such as artificial intelligence, machine learning, robotics etc. are also throwing a challenge as they are creating machines that are smarter and reliable like humans and aim to perform better than human beings. These areas are actively doing R&D for channelizing the complete automation of the machines [39]. For this matter, the talent that is required will solely depend on the pace, extent of the automation and certainly on the skills of the manufacturers. Nowadays, robotics aim to prepare robots that possess cognitive abilities such as analyzing, decision making and reasoning [38].

Such rapid and relevant advancements pertaining to the need of computer knowledge and skills will eventually drive the process of automation faster and more feasible. This will also lead to the transformation of the nature of the work across varied industries [40]. Thus, we can say that improved and better talent is required and is the need of the hour for successful survival in this ever-changing industrial revolution.

Apart from robotics, fields like artificial intelligence are yielding novel smarter machines that are helpful for our industries as well as for the service class. All this may abolish the need of humans any more in near future. Such expanded automation may pose a threat to the human workforce jobs and occupations as well [41]. When everything will be automated then why there is need of humans in the industries. The answer is that both are needed. Machine needs humans for they are the creators of them. Humans need machines for their assistance [42, 43]. Figure 7 shows the two types of talent development skills.

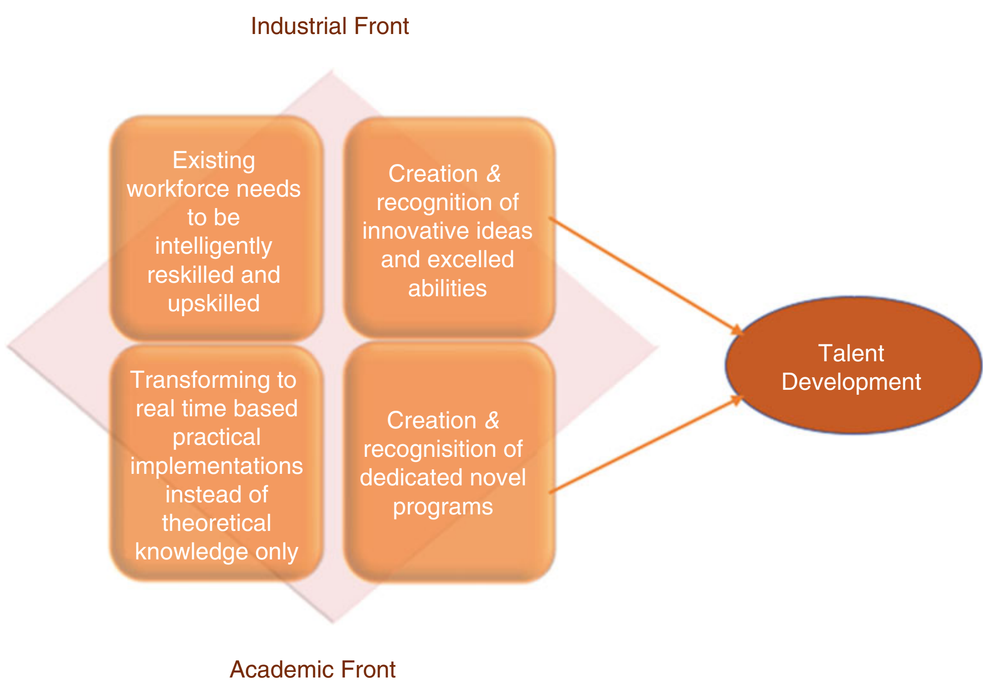


Fig. 7 Talent development skills

Hence, we can say that this fourth industrial revolution is an era of automated advancements having its foundations from robotics, machine learning, artificial intelligence, real time systems etc. [44]. It is also facilitating the increasing growth of IoT known as Internet of Things. The main idea behind IoT implementation is to make the machines talk to each other. As we know, industry 4.0 is combination of machines and humans i.e. we may also quote that it is integration of cyber-physical systems and humans [45]. This novel hybrid combination aim to produce more and more jobs and occupations. This overlapping of human interaction and machine digitization will also create novel business ventures.

Apart from this positive side, it may also lead to few of the losses and displacements in terms of jobs. Novel tools, technologies and business will of course demand more talented, skilful and technical individuals. Existing ones will either need to learn and adapt themselves with the changing needs or the industry will replace them with the new talents or with new machines [46–49]. This will eventually lead to job losses. We can say that this digitalization is on one side taking away the jobs as well as on the other side, it is creating new job opportunities and employment [50].

Need of Skilled Talent in the Digitized World *A very famous African proverb says that, "an army of lions headed by a sheep can be conquered by an army of sheep headed by a lion".*

It speaks that need of talented, skilled and intelligence workforce is required for efficient and effective working of any organization or for any services. These workforce needs to be excelled in excellence in their technical abilities and innovative ideas that could help in making of Industry 4.0. For achieving this, both the industry and the academics needs to join hands and update themselves with the below specified skills as well [51–53].

For able to pursue with the above required guidelines and strategies, hybrid of technology and skills are equally evident [54]. This cross technological platform can be imperative for the fourth industrial revolution as shown in Fig. 8.

This industrial revolution is at its budding stage whereas our production and manufacturing industries are emerging and expanding at a very splendid pace. So we can say that there is substantial amount of scope for throughout growth and enhancements. All this will eventually aid in thus generating lots of revenue that could be utilized by enterprises and service providers provided that skilled, capable and talented individuals are involved in the process.

5 Business Development in Industry 4.0

Fourth industrial revolution is marked by a series of momentous events that are spurred by various inter-connected digitization technologies. The graph of this digitization is dynamically changing and uprising transforming varied business, markets and companies. The hybridization of these techniques entails the integration of the real physical world to the virtual world [52]. This globalization paves the way for expansion and emergence of novel business framework, ideas, machineries, and production companies [53, 55–57]. Hence, we can say that business development is equally evident in Industry 4.0.

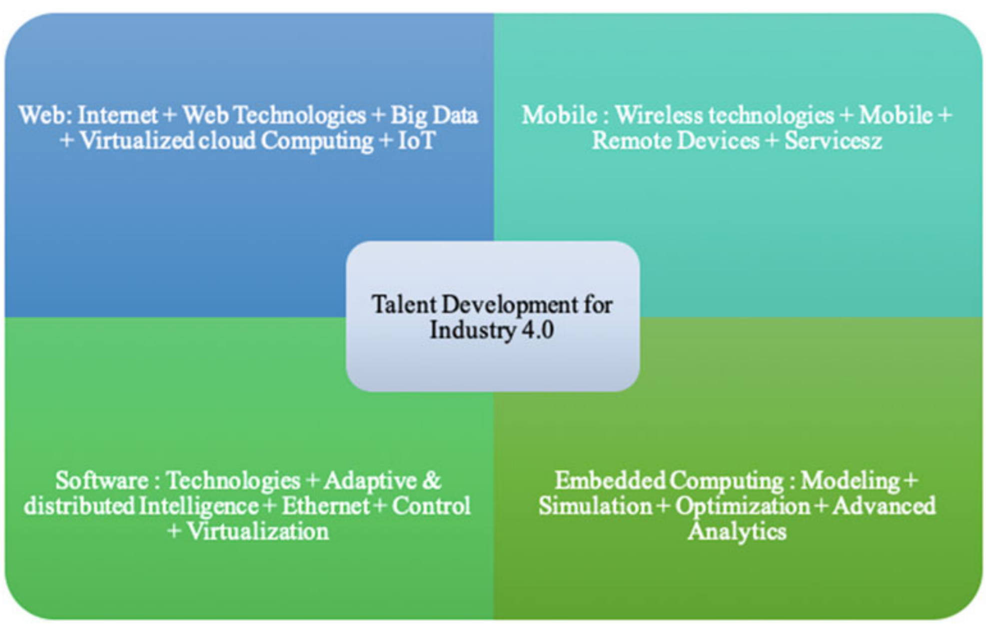


Fig. 8 Cross technological and functional platform needed for talent development in Industry 4.0

Fig. 9 Impact of business development in Industry 4.0

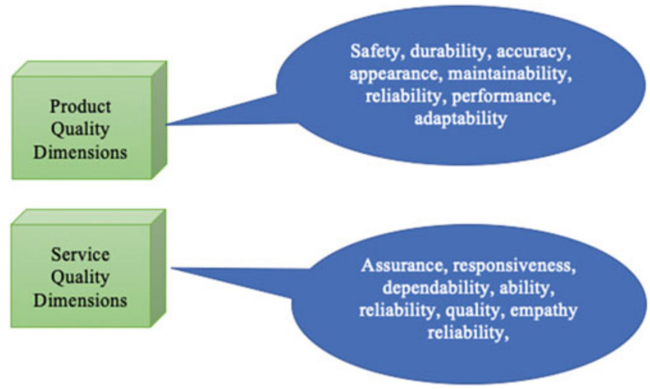


Fig. 10 Dimensions of business development in Industry 4.0

Industry 4.0 has opened the gates for advancements of various tools and technologies based on the competent market strategies that could effectively provide benefits to the entrepreneurs, manufactures, companies and service providers [49]. It is always beneficial to strategically think towards extending long term goals for the breeding manufactures. It is constantly re-shaping and re-modeling the earlier ways of manufacturing and supply [14]. Subsequently, it is advised to make profits out of it and convert these opportunities into competitive benefits. The overall impact of this collision will enhance the business perspectives and ensure higher efficiency, quality, speed and delivery [16, 22, 58]. These are depicted with the help of Fig. 9.

Web 2.0 tools and technologies have helped with the digitalization of the industries in order to produce novel ways of expanding business. Earlier, business only talks about production and expansion of goods and services. Nowadays, it involves digitization and automation of the production and manufacturing processes as well. These are categorized into two dimensions, *product and service quality* [15] as shown in Fig. 10.

Goods and services are often measured based on these two dimensions. Former includes the parameters such as durability-safety-accuracy-appearance-maintainability-performance-reliability-ease of use [59]. Whereas the later one focuses more on the service oriented nature of the business such as quality, independent nature, less of the dependence, physical attributes, domain expertise knowledge, having interest in the customers to tackle their issues and satisfy them and individualization.

These dimensions also aid towards building strong business strategies depending on the companies' available resources and competencies. Again, this business strategy could be categorized as technology driven, customer driven and utility driven [60–62] as shown in Fig. 11.

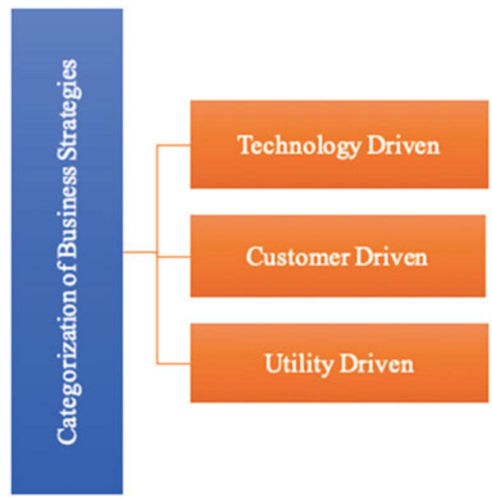


Fig. 11 Strategies of business development in Industry 4.0

Technology-driven states that the market needs ought to be fulfilled via latest technological innovation. Customer-driven focus on the identification and analysis of the needs of the customers for preparing a solution as per their needs for obtaining customer value and satisfaction [63]. Whereas utility-driven emphasizes on recognizing the true needs of the product and the services beyond the customer satisfaction level.

Mutual convergence of these dimensions, aspects and strategies would help to transform the humongous amount of user-generated data into some value offerings with the help of automation and digitization at the global level in order to feed nearly all the businesses. Latest technological innovations, skilled talents, equipped resources, apt capital, automation, digitization, optimization and experimentation would eventually aid the *Fourth Industrial Revolution* to rise, expand and excel globally.

6 Horizontal and Vertical System Integration

There are multiple factors involved in any successful business including quality development, efficient marketing, distributors and suppliers and most importantly customers and the competitors. Smart factories in the new revolution tries to interconnect the machines, materials and the products [64]. To take the business to the up-most level, all the factors contributing to it should have effective communication. Industry 4.0 has therefore Horizontal and Vertical system integration to make the manufacturing process even more smooth. There exist one more type of integration known as the end-to-end integration.

Horizontal Integration The working of any manufacturing industry starts with the demand from the customer, then the supplier supplies the raw material to the factory, where raw material is processed to generate the product, then this product is sent to the distributors, which further supplies it to retailers and then it reaches to the customer. Now suppose in a car manufacturing industry, the customers requested for modification in his car as for the engine and the color to the company. Now the product will be received by the factory, where after analyzing the customers' requirement, they will request the supplier for the material needed [65]. It will take supplier to arrange and then supply the material. After receiving the material factory will update the car and send to the distributor to again send back to the customer. Now, this whole process took time, because the information was provided only to the factory. If at the same time the customer has made the request, the information has been conveyed to all the stakeholders involved in the process, then the taken to deliver the car back to factory will have been utilized by the supplier to arrange and supply the material, and while the product was in upgradation process, distributor has found which retailer can deliver the car to customer and after the product being ready, the car can directly be sent to the retailer. The time consumed in the second scenario will be lot lesser than the first case.

This communication of all the stake holders involved in the supply chain of a product is a Horizontal Integration. By having horizontal integration, all the stakeholders will be connected to a cloud which will keep everyone updated while maintaining the security. Like in smart factory the machines/CPS knows the status of the material, here in similar way the factory, distributor, supplier, retailer, customer and other stake holders are connected.

Horizontal integration solves the problem for the company and customer but the other stakeholders are put into the trouble, as the same supplier might be supplying to different companies, and a retailer has the product of different companies, When the data of all the stakeholders will be linked by Cloud Computing, it will lead to the breach of confidentiality and privacy [66–68]. If a supplier has only one quantity of the engine, and two competitor companies request for the same, and he supplied the one requesting first, and informing the second one that it's out of stock, and soon the requirement will be satisfied, As the supplier is stakeholder in both the companies his data will be on both clouds leading to the trouble with the second company [69]. While implementing the horizontal integration in the future companies, the privacy aspect of all stakeholders need to be given the utmost importance. The basic structure of Horizontal integration is shown in Fig. 12.

By the inter-corporation horizontal integration, related corporations can form an efficient ecosystem. Information, finance, and material can flow fluently among these corporations. Therefore, new value networks as well as business models may emerge. This is needed as the product lifecycle composes of several phases that have to be performed by different corporations [8].

Vertical Integration Vertical integration in contrary to horizontal integration works within an organization. In horizontal integration, the purpose was to create an inter-connected network between all the stakeholders which may or may not belong to a single organization. Vertical integration is performed to bring transparency in the organization. In [58] they defined vertical integration as the merging of planning and development with the production.

A factory owns several different units, such as RFID and sensors, control, production management, manufacturing, and corporate planning. It is essential to vertical integration of actuator and sensor signals across different levels right up to the enterprise resource planning (ERP) level to enable a flexible and reconfigurable manufacturing system. By this integration, the smart machines form a self-organized system that can be dynamically reconfigured to adapt to different product types; and the massive information is collected and processed to make the production process transparent [31].

In any organization, the decisions taken by higher management are not known to the workers at the floor level, they just know how to do the work (manufacturing), and they do it every day, while at higher levels, the senior management decide how they are going to market that product, and what is the current demand, what the competitors are developing. Because in industry 3.0, the workers working at the floor level might not understand such concepts, and as they do mass production of same product, there is nothing new that they have to learn. In industry 4.0, the focus is on customer satisfaction by developing the customizable product, and now rather than humans' smart machines manufacture those products at the floor level [70]. So, whenever a new request comes, it should be conveyed to the floor level too. As the smart factories has inter-connected machines and they have the knowledge when a product is

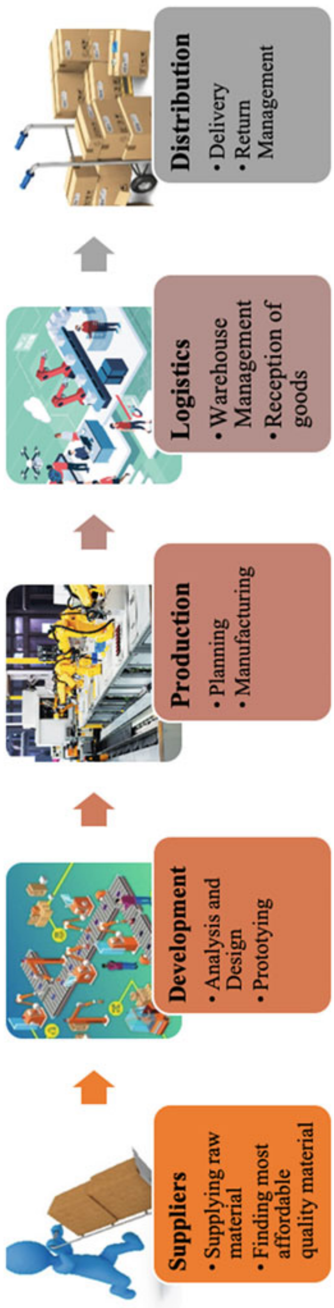


Fig. 12 Horizontal integration in Industry 4.0

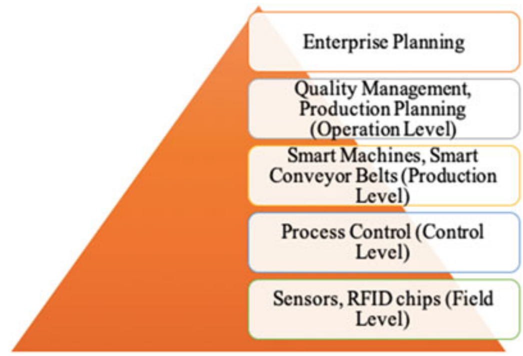


Fig. 13 Vertical integration in Industry 4.0

developed, they can themselves change the status of the product online, it makes the process easier and transparent to the customer and senior management. In nutshell, Vertical integration is an interconnection of different modules of an organization to develop flexible products as shown in Fig. 13.

Industry 4.0 integrates horizontally across the different organizations, from suppliers to the customers and all the other members involved in the development of the product as well as integrates vertically by hierarchical subsystems inside a factory to create flexible and reconfigurable manufacturing system. Industry 4.0 enables ubiquitous sensors, embedded terminal systems, intelligent control systems, and communication facilities to form an intelligent network within the CPS. Interconnection may be man to man, man to machine, machine to machine or service to service, in order to achieve complete horizontal, vertical integration [29]. It makes all data about operations processes, process efficiency and quality management, as well as operations planning are available real-time, supported by augmented reality and optimized in an integrated network [71]. With this networked production, interconnections and information exchange among departments and companies will increase, thus making integration and communication more important.

7 Supply Chain 4.0

Industry 4.0 is not just a smart factory or smart machines, it is concept of automation of complete end to end process including the process of supply chain management (SCM). Supply chain is a vast concept understood in different terms by different personnel's, some consider it to just the process of managing the product supplies, other include the intercommunication between the industries providing the materials to the organization (suppliers), some includes the process of customer feedback to the supply chain management, although indeed it is the process which begins when a customer requests for a product, SCM ensures the material needed to build that product, then after the manufacturing process the product is being shipped to the customer overlooked by SCM [59–62, 72]. SCM ensures the delivery of the product and analyses the customer feedback to overlook the future orders. Swaminathan in 2001 defined Supply Chain as the "set of entities that are involved in the design of new products and services, procuring raw materials, transforming them into semi-finished and finished products and delivering them to end to end customers." [73–76]. Whereas the process of manufacturing a product starting from the raw material till it reaches the customer is known as Value Chain. The difference between Value chain and the supply chain is that designing the value chain works as a roadmap for the development process, and assists in analyzing and optimizing the process to gain more profit [77, 78], and supply chain is the process to ensure that customer gets the product ordered and that too in the time limit. Value chain ensures profit for the organization, supply chain ensures the delivery of the product.

The Smart Supply chain process used in Industry 4.0 is known as Supply Chain 4.0 or Logistics 4.0 [79]. The focus of Supply chain 4.0 has moved from delivery of product to the pre-planning the process by analyzing the demands and feedbacks of customers. Supply Chain 4.0 will reward the future industries in following ways [80]:

- Faster Delivery Time: With industry 4.0, we are analyze the big data generated from every field including the Social Web, with the proper analytics of this data, we can predict the demand of the products, resulting in the fast dispatch of the product on order [78]. Also with the digitization of everything, the routes can be optimized by analyzing the traffic too resulting in accurate prediction of Shipment time.
- Flexibility: Smart logistics analyze the data continuously, prepared for any change in the demand and supply. Smart logistics manages the database of materials availability from different suppliers, dynamic change in the demand will be handled conveniently because of having the resources on the disposal.
- Customization: With more resources available, the request of the customers to design specific products became more feasible and affordable with the help of smart machines.
- Accurate: With the process being transparent between the stakeholders, the time required to receive materials, and to manufacture the product and time to deliver the product can be estimated accurately. The centralized system also helps in efficient management of the resources, generating more profits.

Fig. 14 Foundation of supply chain 4.0

McKansy & Company has given the six main value drivers that are significantly improved by Supply Chain 4.0: Planning, Physical Flow, Performance Management, Order Management, Collaboration and Supply Chain Strategy. Supply Chain reduces the cost among Lost sales and services, Transport and warehousing, Administrative and Inventories [78, 81].

Supply chain 4.0 transforms the business only if it has the strong foundations as shown in Fig. 14. If only the right data is being collected, it can be used to make predictions, the data containing user's marks in mathematics will not help in determining their chance of buying toothpaste of a brand.

Data itself doesn't convey anything until processed to convert it into the information, information is used to make knowledgeable prediction for the business. Having the abilities to convert the data to information is critical for implementation of successful digitized company [71, 80]. To perform the analytics the right hardware and software are inevitable, the analysis of big data without adequate support is not possible. Supply chain involves the analysing of the real-time data, to process the dynamic change the innovation, talent is required to successfully satisfy the new dynamic requests. Last foundation of the supply chain 4.0 is the well-defined processes of the supply-chain sub functions. Undefined procedure can't ensure the quality of the products [82, 83].

Once an organization have the well-defined Supply chain it will have better decision making capabilities along with the innovative products and end-to-end customer engagement ensuring the satisfaction of the customers [84]. Supply Chain 4.0 along with Smart Factories with factual talent and technology will lead to the successful digital transformation of industries into Industry 4.0 with boosted customer satisfaction.

8 Conclusion

With the rise of technological progresses, inventions and innovative ideas, the prime focus has been shifted more towards enhancing Industrial revolution 4.0 and this revolution is becoming more sophisticated and multifaceted day-by-day. Development of Industry 4.0 predominantly is an era of cyber-physical-systems, smart factories and IoT [85]. All this has upgraded this revolution at a higher level. In this chapter, we have learned the evolution of industrial revolutions and how these advancements has helped in supporting, automating and dynamically reconfiguring the manufacturing process which hails the talent and business development. These expansions, developments and manufacturing is quite well handled by technologies such as artificial intelligence, cloud computing, social media analytics, big data analytics etc. The collaborative unison of all these has pivoted sharply towards smart and steady automation. In this chapter, we have understood paradigms of Industry 4.0, its key objectives and related perspectives in the current scenario. We can say that Industry 4.0 is developing at a faster pace and is in a transition state indeed, but yet not developed fully. Due to rising technological needs of the society, and learning from the collective intelligence aspects of Industry 4.0, we are aiming to enter into the era of Industry 5.0 that is going to be more focused on the customized manufacturing depending upon the interaction and collaboration between the men and the machines.

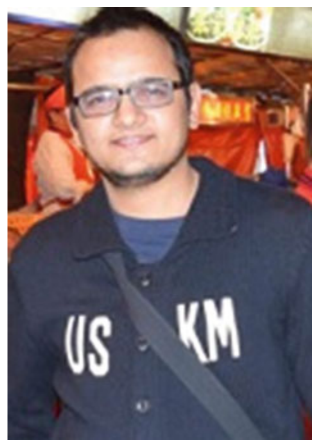
References

1. Gilchrist, A. (2016). Industry 4.0: the industrial internet of things. Apress.
2. Industry 4.0. Available Online at: (https://en.wikipedia.org/wiki/Industry_4.0)
3. http://www.apics.org/apics-for-individuals/apics-magazine-home/magazine-detail-page/2017/09/20/industry-1.0-to-4.0-the-evolution-of-smart-factories
4. Industry 4.0: Definition, Design Principles, Challenges, and the Future of Employment, https://www.cleverism.com/industry-4-0/.
5. Wan, J., Tang, S., Shu, Z., Li, D., Wang, S., Imran, M., & Vasilakos, A. V. (2016). Software-defined industrial internet of things in the context of industry 4.0. IEEE Sensors Journal, 16(20), 7373-7380.
6. https://www.forbes.com/sites/bernardmarr/2018/09/02/what-is-industry-4-0-heres-a-super-easy-explanation-for-anyone/#8105a7e9788a
7. Kolberg, D., & Zühlke, D. (2015). Lean automation enabled by industry 4.0 technologies. IFAC-PapersOnLine, 48(3), 1870-1875.
8. "Global Industry 4.0 Survey: Building the digital enterprise", www.pwx.com/industry40.
9. Gorecky, D., Schmitt, M., Loskyll, M., & Zühlke, D. (2014, July). Human-machine-interaction in the industry 4.0 era. In Industrial Informatics (INDIN), 2014 12th IEEE International Conference on (pp. 289-294). Ieee.
10. Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. Manufacturing Letters, 3, 18-23.
11. Almada-Lobo, F. (2016). The Industry 4.0 revolution and the future of manufacturing execution systems (MES). Journal of innovation management, 3(4), 16-21.
12. Faller, C., & Feldmüller, D. (2015). Industry 4.0 learning factory for regional SMEs. Procedia CIRP, 32, 88-91.
13. Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., Harnisch, M. (2015). Industry 4.0: The future of productivity and growth in manufacturing industries. *Boston Consulting Group*, *9*.
14. Das, S., & Nayyar, A. (2019). Innovative Ideas to Manage Urban Traffic Congestion in Cognitive Cities. In *Driving the Development, Management, and Sustainability of Cognitive Cities* (pp. 139-162). IGI Global.
15. Kumar, A., Sharma, A., Sharma, S., & Kashyap, S. (2017, July). Performance analysis of keyword extraction algorithms assessing extractive text summarization. In *2017 International Conference on Computer, Communications and Electronics (Comptelix)* (pp. 408-414). IEEE.
16. Kumar, A., Sharma, A., Sharma, S., & Kashyap, S. (2017, July). Performance analysis of keyword extraction algorithms assessing extractive text summarization. In *2017 International Conference on Computer, Communications and Electronics (Comptelix)* (pp. 408-414). IEEE.
17. Hermann, M., Pentek, T., & Otto, B. (2016, January). Design principles for industries 4.0 scenarios. In System Sciences (HICSS), 2016 49th Hawaii International Conference on (pp. 3928-3937). IEEE.
18. Vidic, B., & Weitlauf, H. M. (2002). Horizontal and vertical integration of academic disciplines in the medical school curriculum. Clinical Anatomy: The Official Journal of the American Association of Clinical Anatomists and the British Association of Clinical Anatomists, 15(3), 233-235.
19. http://www.milkfacts.info/Milk%20Processing/Yogurt%20Production.html.
20. Li, L. (2018). China's manufacturing locus in 2025: With a comparison of "Made-in-China 2025" and "Industry 4.0". Technological Forecasting and Social Change, 135, 66-74.
21. Wang, S., Wan, J., Li, D., & Zhang, C. (2016). Implementing smart factory of industries 4.0: an outlook. International Journal of Distributed Sensor Networks, 12(1), 3159805.
22. Hecklau, F., Galeitzke, M., Flachs, S., & Kohl, H. (2016). Holistic approach for human resource management in Industry 4.0. *Procedia CIRP*, *54*, 1-6.
23. Lee, H. Kao and S. Yang, "Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment", Procedia CIRP, vol. 16, pp. 3-8, 2014. Available: https://doi.org/10.1016/j.procir.2014.02.001.
24. B. Chen, J. Wan, L. Shu, P. Li, M. Mukherjee and B. Yin, "Smart Factory of Industry 4.0: Key Technologies, Application Case, and Challenges", IEEE Access, vol. 6, pp. 6505-6519, 2018. Available: https://doi.org/10.1109/access.2017.2783682.
25. T. Stock and G. Seliger, "Opportunities of Sustainable Manufacturing in Industry 4.0", Procedia CIRP, vol. 40, pp. 536-541, 2016. Available: https://doi.org/10.1016/j.procir.2016.01.129.
26. Y, Lu, "Industry 4.0: A survey on technologies, applications and open research issues", Journal of Industrial Information Integration, vol. 6, pp. 1-10, 2017. Available: https://doi.org/10.1016/j.jii.2017.04.005.
27. K. Zhou, Taigang Liu and Lifeng Zhou, "Industry 4.0: Towards future industrial opportunities and challenges," *2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD)*, Zhangjiajie, 2015, pp. 2147-2152.
28. Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. Business & information systems engineering, 6(4), 239–242.

29. Singh, S. P., Nayyar, A., Kumar, R., & Sharma, A. (2019). Fog computing: from architecture to edge computing and big data processing. *The Journal of Supercomputing*, *75*(4), 2070–2105.
30. Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of Production Economics, 204, 383-394.
31. S. Weyer, M. Schmitt, M. Ohmer and D. Gorecky, "Towards Industry 4.0 - Standardization as the crucial challenge for highly modular, multi-vendor production systems", IFAC-PapersOnLine, vol. 48, no. 3, pp. 579-584, 2015. Available: 10.1016/j.ifacol.2015.06.143 [Accessed 3 February 2019].
32. Qin, J., Liu, Y., & Grosvenor, R. (2016). A categorical framework of manufacturing for industry 4.0 and beyond. Procedia Cirp, 52, 173-178.
33. Wan, J., Tang, S., Shu, Z., Li, D., Wang, S., Imran, M., & Vasilakos, A. V. (2016). Software-defined industrial internet of things in the context of industry 4.0. IEEE Sensors Journal, 16(20), 7373-7380.
34. Gorecky, D., Schmitt, M., Loskyll, M., & Zühlke, D. (2014, July). Human-machine-interaction in the industry 4.0 era. In Industrial Informatics (INDIN), 2014 12th IEEE International Conference on (pp. 289-294). Ieee.
35. Singh, P., Gupta, P., Jyoti, K., & Nayyar, A. (2019). Research on Auto-Scaling of Web Applications in Cloud: Survey, Trends and Future Directions. *Scalable Computing: Practice and Experience*, *20*(2), 399-432.
36. Das, S., & Nayyar, A. (2019). Innovative Ideas to Manage Urban Traffic Congestion in Cognitive Cities. In *Driving the Development, Management, and Sustainability of Cognitive Cities* (pp. 139-162). IGI Global.
37. Jazdi, N. (2014, May). Cyber physical systems in the context of Industry 4.0. In Automation, Quality and Testing, Robotics, 2014 IEEE International Conference on (pp. 1-4). IEEE.
38. Lunn, T. (1995). Selecting and developing talent: an alternetive approach. Management Development Review, 8(1), 7-10.
39. Lee, J., Kao, H. A., & Yang, S. (2014). Service innovation and smart analytics for industry 4.0 and big data environment. Procedia Cirp, 16, 3-8.
40. Sivathanu, B., & Pillai, R. (2018). Smart HR 4.0–how industry 4.0 is disrupting HR. Human Resource Management International Digest, 26(4), 7-11.
41. Ustundag, A., & Cevikcan, E. (2017). Industry 4.0: Managing The Digital Transformation. Springer.
42. Li, L. (2018). China's manufacturing locus in 2025: With a comparison of "Made-in-China 2025" and "Industry 4.0". Technological Forecasting and Social Change, 135, 66-74.
43. Zhang, X., Peek, W. A., Pikas, B., & Lee, T. (2016). The transformation and upgrading of the Chinese manufacturing industry: Based on "German Industry 4.0". Journal of Applied Business and Economics, 18(5), 97-105.
44. Newhall, S. (2012). A global approach to talent management: High-quality leaders are the key to competitive advantage. Human Resource Management International Digest, 20(6), 31-34.
45. Lin, K. C., Shyu, J. Z., & Ding, K. (2017). A Cross-Strait Comparison of Innovation Policy under Industry 4.0 and Sustainability Development Transition. Sustainability, 9(5), 786.
46. Harvey, W. (2013). Victory can be yours in the global war for talent: Social factors and lifestyle help to attract top employees. Human Resource Management International Digest, 21(1), 37-40.
47. Corsello, J. (2012). Maximizing talent management through the cloud: New technologies offer opportunities to develop skills and careers. Human Resource Management International Digest, 20(4), 27-30.
48. Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. Business & Information Systems Engineering, 6(4), 239-242.
49. Prause, G. (2015). Sustainable business models and structures for Industry 4.0. Journal of Security & Sustainability Issues, 5(2).
50. Qin, J., Liu, Y., & Grosvenor, R. (2016). A categorical framework of manufacturing for industry 4.0 and beyond. Procedia Cirp, 52, 173-178.
51. Rennung, F., Luminosu, C. T., & Draghici, A. (2016). Service provision in the framework of Industry 4.0. Procedia-Social and Behavioral Sciences, 221, 372-377.
52. Petrasch, R., & Hentschke, R. (2016, July). Process modeling for Industry 4.0 applications: Towards an Industry 4.0 process modeling language and method. In Computer Science and Software Engineering (JCSSE), 2016 13th International Joint Conference on (pp. 1-5). IEEE.
53. Erol, S., Schumacher, A., & Sihn, W. (2016). Strategic guidance towards Industry 4.0–a three-stage process model. In International conference on competitive manufacturing (Vol. 9, pp. 495-501).
54. Alicke, K., Rexhausen, D., & Seyfert, A. (2017). Supply chain 4.0 in consumer goods. *Mckinsey & Company*.
55. Schumacher, A., Erol, S., & Sihn, W. (2016). A maturity model for assessing industry 4.0 readiness and maturity of manufacturing enterprises. Procedia CIRP, 52, 161-166.
56. Burritt, R. L., Hahn, T., & Schaltegger, S. (2002). Towards a comprehensive framework for environmental management accounting—Links between business actors and environmental management accounting tools. Australian Accounting Review, 12(27), 39-50.
57. Qin, J., Liu, Y., & Grosvenor, R. (2016). A categorical framework of manufacturing for industry 4.0 and beyond. *Procedia Cirp*, *52*, 173-178.
58. Schuh, G., Potente, T., Wesch-Potente, C., Weber, A. R., & Prote, J. P. (2014). Collaboration Mechanisms to increase Productivity in the Context of Industrie 4.0. *Procedia CIRP*, *19*, 51-56.
59. Kumar, A., & Joshi, A. (2017, March). Ontology driven sentiment analysis on social web for government intelligence. In *Proceedings of the Special Collection on eGovernment Innovations in India* (pp. 134-139). ACM.
60. A. Sharma, R. Ranjan, "Software Effort Estimation using Neuro Fuzzy Inference System: Past and Present" published in International Journal on Recent Innovation Trends in Computing and Communication (IJRITCC), ISSN: 2321-8169, Vol.5, Issue.8, Pp: 78-83.
61. Gehrke, Lars & T. Kühn, Arno & Rule, David & Moore, Paul & Bellmann, Christoph & Siemes, Sebastian & Dawood, Dania & Singh, Lakshmi & Kulik, Julie & Standley, Matthew. (2015). A Discussion of Qualifications and Skills in the Factory of the Future: A German and American Perspective.
62. Industry 4.0: the fourth industrial revolution – guide to Industrie 4.0, https://www.i-scoop.eu/industry-40/#Industrie_40_principles_horizontal_and_vertical_integration
63. Lu, L. X., & Swaminathan, J. M. (2013). Advances in Supply Chain Management.
64. "Supply Chain 4.0-The next generation Digital Supply Chain", https://www.mckinsey.com/business-functions/operations/our-insights/supply-chain-40%2D%2Dthe-next-generation-digital-supply-chain
65. What is Value Chain, https://www.businessnewsdaily.com/5678-value-chain-analysis.html
66. Lee, J., Kao, H. A., & Yang, S. (2014). Service innovation and smart analytics for industry 4.0 and big data environment. *Procedia Cirp*, *16*, 3-8.
67. Stock, T., & Seliger, G. (2016). Opportunities of sustainable manufacturing in industry 4.0. *Procedia Cirp*, *40*, 536-541.
68. Benešová, A., & Tupa, J. (2017). Requirements for Education and Qualification of People in Industry 4.0. *Procedia Manufacturing*, *11*, 2195-2202.
69. Swaminathan, J. M. (2001). Enabling customization using standardized operations. *California Management Review*, *43*(3), 125-135.

70. Kumar, A., & Sebastian, T. M. (2012). Machine learning assisted sentiment analysis. In *Proceedings of International Conference on Computer Science & Engineering (ICCSE'2012)* (pp. 123-130).
71. Kumar, A., Khorwal, R., & Chaudhary, S. (2016). A survey on sentiment analysis using swarm intelligence. *Indian J Sci Technol*, *9*(39), 1-7.
72. Kumar, A., Khorwal, R., & Chaudhary, S. (2016). A survey on sentiment analysis using swarm intelligence. *Indian J Sci Technol*, *9*(39), 1-7.
73. Nayyar, A., Puri, V., & Le, D. N. (2017). Internet of nano things (IoNT): Next evolutionary step in nanotechnology. *Nanoscience and Nanotechnology*, *7*(1), 4-8.
74. Singh, P., Gupta, P., Jyoti, K., & Nayyar, A. (2019). Research on Auto-Scaling of Web Applications in Cloud: Survey, Trends and Future Directions. *Scalable Computing: Practice and Experience*, *20*(2), 399-432.
75. Singh, S. P., Nayyar, A., Kumar, R., & Sharma, A. (2019). Fog computing: from architecture to edge computing and big data processing. *The Journal of Supercomputing*, *75*(4), 2070-2105.
76. Kumar, A., & Joshi, A. (2017, March). Ontology driven sentiment analysis on social web for government intelligence. In *Proceedings of the Special Collection on eGovernment Innovations in India* (pp. 134-139). ACM.
77. Ranjan, R., & Sharma, A. (2019). Evaluation of Frequent Itemset Mining Platforms using Apriori and FP-Growth Algorithm. *arXiv preprint arXiv:1902.10999*.
78. Kumar, A., & Joshi, A. (2017, March). Ontology driven sentiment analysis on social web for government intelligence. In *Proceedings of the Special Collection on eGovernment Innovations in India* (pp. 134-139). ACM.
79. Kumar, A., & Khorwal, R. (2017). Firefly algorithm for feature selection in sentiment analysis. In *Computational Intelligence in Data Mining* (pp. 693-703). Springer, Singapore.
80. Nayyar, A., Jain, R., Mahapatra, B., & Singh, A. (2019). Cyber Security Challenges for Smart Cities. In *Driving the Development, Management, and Sustainability of Cognitive Cities* (pp. 27-54). IGI Global.
81. Kumar, A., & Sebastian, T. M. (2012). Machine learning assisted sentiment analysis. In *Proceedings of International Conference on Computer Science & Engineering (ICCSE'2012)* (pp. 123-130).
82. "Logistics 4.0 and Smart supply chain management in Industry 4.0", https://www.i-scoop.eu/industry-4-0/supply-chain-management-scm-logistics/
83. Jain, D. K., Kumar, A., Sangwan, S. R., Nguyen, G. N., & Tiwari, P. (2019). A Particle Swarm Optimized Learning Model of Fault Classification in Web-Apps. *IEEE Access*, *7*, 18480-18489.
84. Solanki, A., & Nayyar, A. (2019). Green Internet of Things (G-IoT): ICT Technologies, Principles, Applications, Projects, and Challenges. In *Handbook of Research on Big Data and the IoT* (pp. 379-405). IGI Global.
85. Batth, R. S., Nayyar, A., & Nagpal, A. (2018, August). Internet of Robotic Things: Driving Intelligent Robotics of Future-Concept, Architecture, Applications and Technologies. In *2018 4th International Conference on Computing Sciences (ICCS)*(pp. 151-160). IEEE.

Aditi Sharma is currently working as an Assistant Professor at DIT University, Dehradun, India. She has done her B.Tech in Computer Science And Engineering from Punjabi university, Patiala and M. Tech in Software Engineering from Delhi technological University, Delhi, India in 2015 and 2017 respectively. She is currently pursuing Ph.D. from Delhi technological University. Her research interests include Text Summarization, Social Web Analysis, Fuzzy Logic, Software Engineering, Cyber Bullying.



Deepak Kumar Jain is an Assistant Professor at Chongqing University of Posts and Telecommunications, Chongqing, China. He received the degrees of Bachelor of Engineering from Rajiv Gandhi Proudyogiki Vishwavidyalaya, India and Master of Technology from Jaypee University of Engineering and Technology, India in 2010 and 2012, respectively. He completed his Ph. D. from University of Chinese Academy of Sciences, Institute of Automation, Beijing, China. He has presented several papers in peer reviewed Conferences, as well as published numerous studies in science cited journals. His areas of research are deep learning, machine learning, pattern recognition, and computer vision.

Sustainable Development in Industry 4.0

Saurabh Raj Sangwan and M. P. S. Bhatia

Abstract

The manufacturing industries nowadays is rapidly changing towards customized production and the need for today's industry involves the manufacturing process which is both digital and intelligent. The newest revolution in the era is termed as Industry 4.0, controls the entire life cycle of the product and has the potential to produce innovative solutions for global issues faced in sustainable development. There are broad 17 challenges faced while having the sustainable development and is constantly questioned with the development of every new business model. These challenges are set to achieve the global fair and sustainable health by maintaining the good and peaceful relationship between the people and planet. To overcome these challenges the elements of industry 4.0 is set to achieve sustainable development in the three dimensions—economic, social and ecological. The economic dimension of sustainability focus on economic performance, market presence, indirect economic impacts and procurement practices. It is linked to ecological dimension in relation to the use of energy and resources, and social dimension in relation to safeguarding and creation of workplaces. The social dimension of sustainability focus on providing equity and safety to employees, stakeholders and community in which they operate. And the Ecological dimension of sustainability focus on preserving the three basic functions—the supply function, the waste receiver and the direct usefulness with the aim that the non-renewable resources must be replaced by renewable resources, and the consumption of the renewable resources to be some extent so that they can be regained in the future.

Keywords

Industry 4.0 · Sustainable development · Tools · Triple bottom line · Economic dimension · Ecological dimension · Social dimension

1 Introduction

Over the last few years, industry 4.0 has spellbound attention from all around the world. But, the current globalization is faced by many challenges to meet the continuously increasing worldwide demand for both capital and consumer goods by concurrently ensuring a sustainability in its social, environmental and economic dimensions. Now, the industrial value creation in the industrialized countries is mainly shaped by the development focusing towards the fourth stage of industrialization, which we know as so-called Industry 4.0. Thus, we can define industry 4.0 as—it is not just about the production [1], but also how creating and design of various products, processes, programs, community, society and business functions due to the involvement of artificial intelligence, machine learning, hardware, software, and the humans. This development of industry 4.0 provides multiple opportunities for the realization and adoption of sustainable manufacturing.

For centuries, human needs including food, cloths, houses were manufactured either by hand or by forcing the work animal to help manufacture the same. As the time evolved, manufacturing began to change rapidly with the introduction of various technological advancements and as a result development operations drastically increased from there. The major technological advancements of the Fourth Industrial Revolution, or Industry 4.0, are revolutionizing industrial production. The First Industrial Revolution evolved in the 1800s with the development of steam and water powered machines to help the workers.

S. R. Sangwan (✉) · M. P. S. Bhatia
Division of Computer Engineering, Netaji Subhas University of Technology, Delhi, India

A. Nayyar, A. Kumar (eds.), *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-14544-6_3

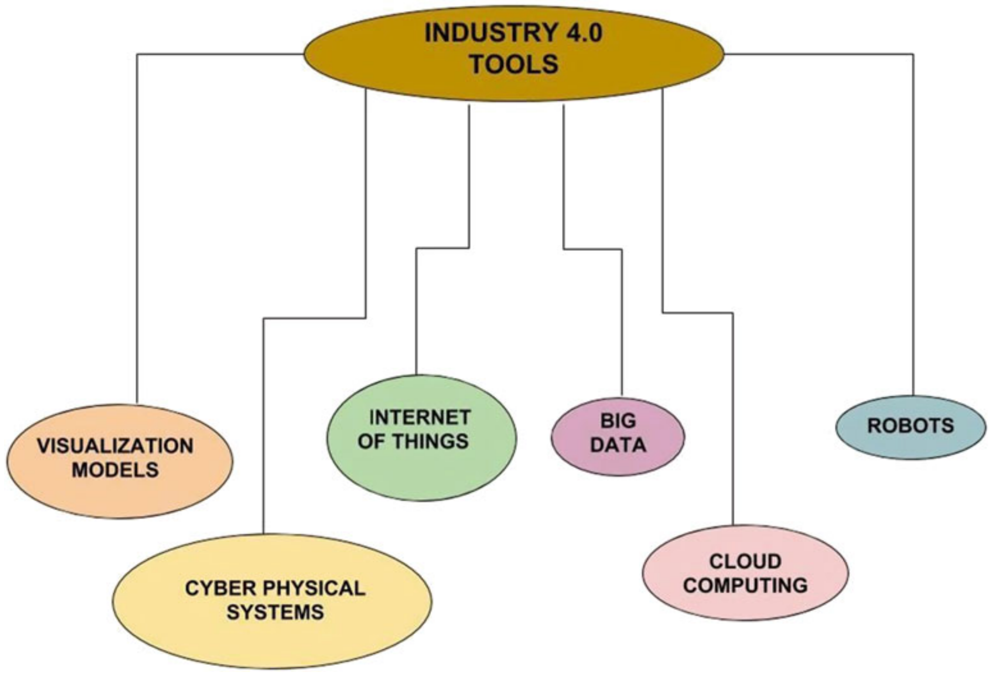


Fig. 1 Tools of Industry 4.0

As the production capacity increased, business grew from single owners taking care of their own as well of their neighbors. Electricity became the first and primary source of power by the beginning of the twentieth century raising to the second industrial revolution making it easier to utilize water and steam enabled businesses to focus power sources to single machines as a result making them more portable. Along with this, several management programs were also developed to rise the effectiveness of manufacturing facilities. The third industrial revolution, in the last few years of the twentieth century, the invention of electronic devices and information technologies made it possible to fully automate the machines. In the twenty-first century, the fourth revolution, Industry 4.0 takes automation self-cognition, connects the internet of things (IOT) with production techniques to guide intelligent steps, cutting-edge technologies like additive, robotics, AI, to help the programs reach their full potential by allowing self-optimization and self-customization.

The creation of the fourth revolution in Industry 4.0 includes various tools or technologies [2] as shown in Fig. 1. Robotics [3], Increases the human-computer interactions by storing information, and the chance of using that information in intelligent ways with the help of Artificial Intelligence. Improving the better representation of the physical world by means of digital equipment. For example, 3D printing. Modeling and simulation technologies [4], includes modern design, piloting, virtual prototyping, and automation in manufacturing industries. Horizontal and vertical system [5], provides the integration between various value chains and between different functional and non-functional layers in an organization. The Industrial Internet of Things [6] in the worlds of mining, manufacturing, transportation, agriculture, healthcare, etc. developing a good bond of these fields between humans and computers.

Cyber security [7] by means of Vigilant resilience is a successful effort which keeps security only at the adaptable level in Industry 4.0. Cloud technologies [8], are a creator of disruptive innovation and a way-creator for a called business fast-lane. It "democratizes" access to learning, knowledge, and communication. Additive manufacturing [9] providing fast connectivity between customer, data, and production. Augmented reality [10] is where the use of an efficient digital toolbox, engineers, designers, or technicians can increment their capabilities of solving problems, also expanding options for optimizing products and processes. Big data and analytics [11], deals with the data. We know data is the driver of the decade, a commodity having much weight than oil. Analyzing data in more fast and efficient ways, big data and analytics cover the method for a transformation of learning, manufacturing, selling, etc. [12].

> Industry 4.0 has the potential to produce innovative solutions to global issues. The SDGs can provide guidance in realizing this potential.

Without affecting much the planet's current condition and increasing the idea of the living being, working and establishing the development of a society leads to Sustainable development. In other words, a development that fulfills the

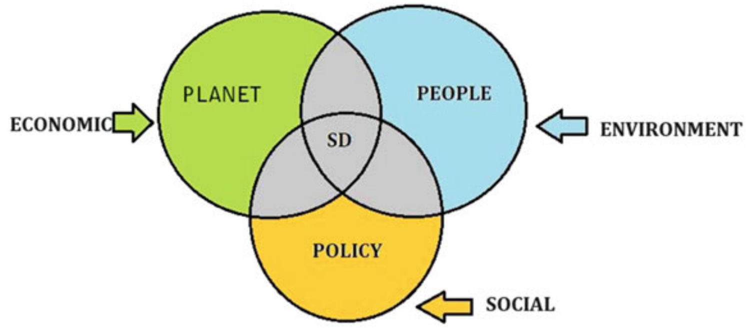


Fig. 2 Sustainability development

demands of the present without sacrificing the upcoming generations needs so that they can also enjoy the resources which we are having today. Figure 2 depicts the true motive of Sustainability Development by showing that it can only be achieved by having a balanced relationship between People, Planet (nature or resources) and the World Organization and management policies. If any one of the three is missing, the goal of sustainable development can't be achieved.

Human-kind faces many issues to make sure that all people have the equal wellbeing opportunities for the same development giving rise to four objectives of sustainable development which covers all different aspects—social progress and social fairness, protection of the environment, natural resources conservation and steady and stable growth of the economy. These can be achieved by lowering pollution, poverty, and unemployment. Also, the balance between production and the destruction of the planet is questioned constantly we know for economic development, Sustainable development is a crucial portion of all countries for which Industry 4.0 has shown many new models to the world, and opportunities for technologies has expanded a lot, along with production, and improvement in various business, the question of sustainability stands. How will the sustainable development affect by new business models, and how will they afford to put the future generation of humanities in the spotlight?

2 Sustainable Development Challenges

The Sustainable development challenges are many in number so as to meet the industry 4.0 requirement which covers the huge area almost the whole universe or even more, it's obvious the challenges will be more in number in coming years. The more the population is increasing, the more need is increasing, but the resources are still constant. Thus, to balance all these things properly various steps need to be taken care carefully then only we can achieve sustainability. In general, the main reasons are:

- Not properly defining goals and scope of goals
- Lack of Monitoring and addressing
- Misunderstanding of the goals
- Less unified standards
- Inaccessibility to various information
- Failing in prioritizing the quality
- Failure of government policy

The Problem is associated with every aspect that is the people, planet, and profit and can be categorized majorly into five P's—People, Planet, Prosperity, Peace, Partnership [13] as shown in Fig. 3. The challenges faced by sustainability [14] precisely can be understood by the picture diagram as shown in Fig. 4.

3 Challenges of Sustainable Development

Sustainable development considers 17 major challenges such as poverty, hunger and others shown in Fig. 4 and are briefly discussed next.

Challenge 1—End Poverty
According to the World Bank, since 2000 the global poverty rates have been reduced to more than half but still one in every ten people along with their families are living on less than the international poverty line of US$1.90 a day. Poverty is not just about lack of income or resources in a country to achieve a sustainable development but it includes hunger, malnutrition, social discrimination, limited access to education and other basic services. In general, the lack to meet general personal needs such as good food, clothes and shelter refer to poverty [15]. Overcoming the poverty in all its forms from everywhere is one of the greatest challenge faced by humanity. With poverty comes the lack of access to resources by people thus leaving people with fewer resources, how can they manage to cope up with the developing world and its opportunities for developing new things.

Measurement of the poverty is required in order to tackle all the problems faced by poverty. The measurement can be classified into two categories. Absolute poverty, refers to the condition when people lack to have the minimum amount of

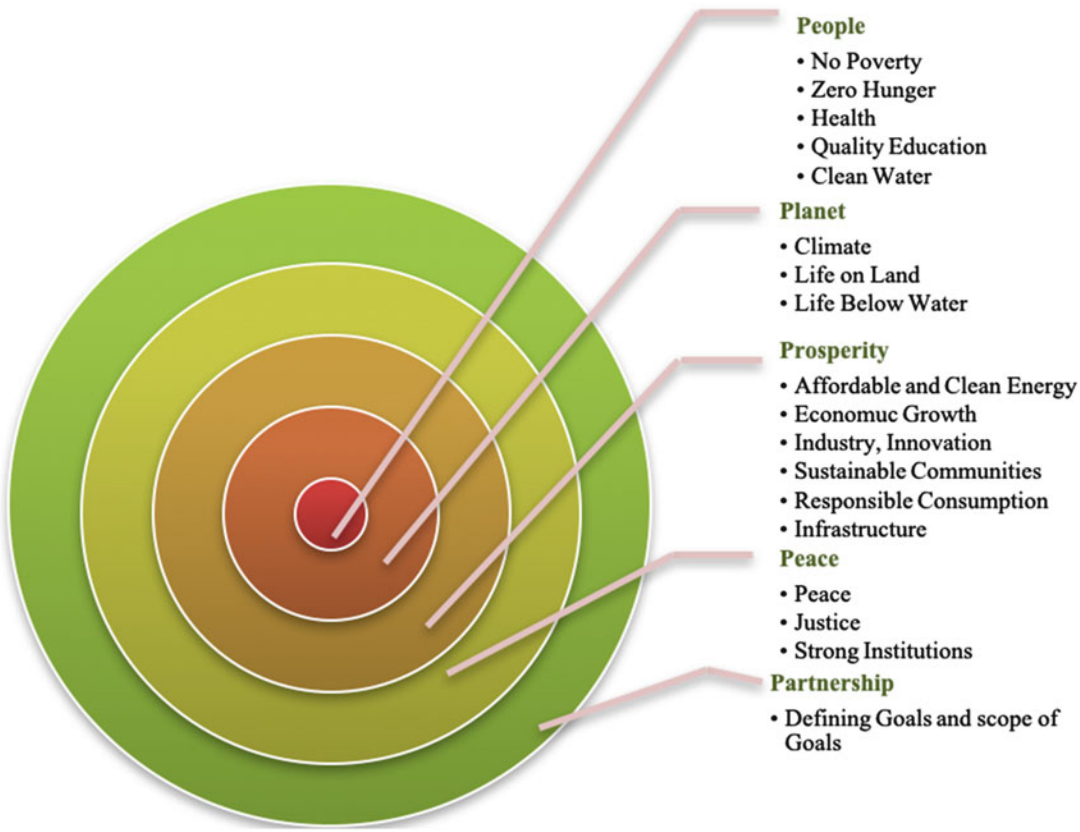


Fig. 3 Five P's of sustainability

income that is needed to meet at least the minimum requirements for the basic living needs over an allowed span of time. It considers the lacking food, clothes, shelter, safe drinking water, sanitation facilities, health, education, information and access to services irrespective of the person's permanent location or span. Whereas relative poverty, refers to the condition when people lack to have the minimum amount of income that is needed to maintain the average living standard. In other words, it is when a person dependent on that country does not enjoy a minimum some threshold level of "living standards" as compared to the other population of that country. Therefore, relative poverty varies from one place to another and it changes over time. For example, for a family which has two adults and two children living in a country like America in nineteenth century if had a yearly income less than say $3000 would have been considered as living in relative poverty whereas by twentieth century this amount increased by $14,500 a year. Ending poverty from everywhere in all its forms, forms the first most essential part of the 2030 sustainable development agenda.

Challenge 2—End Hunger

According to the report published in 2018 by The State of Food Security and Nutrition in the World, in the duration of the years, 1990–1992 the rate of undernourishment in the developing country had decreased from 23.3 to 12.9% of people. But as the decreased in the percentage by half, global hunger began rising. Over the past 3 years, the hunger ratio reaching from one in every nine people [16]. The impacts of hunger can be severe, children can experience stunted growth due to malnourishment or can be severely underweight. So, what's the reason for the drastic increase in hunger? Two main reasons are, the conflicts around the globe, and the extreme change in the climate. It is the time when we have to think how we grow, how we share, and how we consume our food. If everything done in right manner, the agriculture, fisheries and the forestry can provide people with nutritious food, can help generate the good incomes while protecting the environment. At present, there is a rapid degradation in our soils, freshwater, oceans, biodiversity and the forests. Most importantly the change in the climate is putting much pressure on the resources people depend upon leading to the high risk linked with droughts and floods. Unless we profoundly rethink about the global food and agricultural systems it is estimated that the number of people suffering from hunger worldwide could exponentially increase by 2050.

Challenge 3—Ensure Healthy Lives

We know health leads to wealth. What if your health doesn't support you? You will be helpless. With the increase in pollution in every aspect like air, water affecting the people

Fig. 4 Challenges of sustainability

health to an extreme. Pollution leads to the harmful environment [17] that results in an unfavorable effect on living beings resulting in one of the major concern areas for the world. It is a worldwide issue involving the Nations, governments, institutions and the media. About 17,000 children die per day back in 1990, and more than five million children still die within the age of 5 every year. Children born in poor family are almost twice more likely to die before the age of five compare to those children born in wealthier families. Also, the children whose mothers are educated only if with primary schooling are more likely to survive than those children who are raised by the mothers with no education. Since 2000 the maternal mortality rate has fallen by 37%. Around two-thirds declined rate in maternal mortality have been noticed in the Eastern Asia, Northern Africa and Southern Asia. In developing regions, the portion of mothers that does not survive childbirth compared to those mothers who survive childbirth referred as maternal mortality ratio is 14 times higher than the maternal mortality ratio in the developed regions as only half of the mothers in developing regions receive the adequate amount of health care which is required. Diseases such as HIV/AIDS, malaria affecting adversely to the people health. In 2017, 36.9 million people worldwide were living with HIV and 940,000 people died from AIDS and over 6.2 million people die from malaria. People facing difficulty even in breathing, which was till now taken as granted. The days are not so far when we will be buying the fresh air from markets. Thus, its indeed very important urge to ensure healthy lives and promote the well-being at ages is essential to make function everything, well and proper.

Challenge 4—Inclusive and Lifelong Learning

Due to rapid technological change, lifelong learning is a growing issue with quality education [18]. The people worldwide today has more knowledge compare to in earlier days but still not everyone is benefited from it. As a policy intervention, education enables self-reliance, boosts economic growth by improvising skills and opening better opportunities for good livelihoods. Ensuring equal access to education and training is needed so that every individual, regardless of her/his origin, social and economic status, mental illness or physical health condition, gender or age can profit from tailored learning opportunities. The way to lifelong learning is a matter of equal possibility to full participation in society, high-quality jobs and, successfully achieve personal growth. Inequalities in our education and training systems which are particularly negatively affecting vulnerable groups such as migrants and refugees and pushing them to the margins of society. Clearly, educational attainment levels are linked to more and better employment, health, democratic and social participation. Therefore, efforts should be made to give equal opportunities to all eliminating prejudices and discrimination.

Challenge 5—Achieve Gender Equality

Emancipating women and girls with education, expertise in skills and jobs seems to be a key tool to label issue of gender equality [19]. Unfairness against women and girls is a widespread and long-running situation that divides society at every level. Despite knowing that women are the building block of this world yet people, don’t see the women getting equal privileges as men. Empowering women and promoting them is crucial to accelerating sustainable development. Basic human right is not just the ending of all forms of discrimination against women but also a multiplier effect across the other development areas. Since the gender inequality being the one of the history’s most persistent as well as widespread forms of injustice, the elimination of such constitute will be the one of the history’s biggest movements for change. Not just the discrimination but the women also suffers from the violence in every part of the world. Sadly, one in every three women experience at least one time in her lifetime the physical or sexual violence. The gaps in gender equality nearly exists in every sector around the world. For example, In 1990, in South Asia out of every 100 boys only 74 girls were enrolled in primary school. However, by 2012 the enrollment ratio increased but not significantly. The equality in gender is not only a fundamental right of human, but essential foundation for a peaceful and sustainable world.

Challenge 6—Water and Sanitation for All

Clean, pure accessible water is essential part of the world where we want to live in. Although there is sufficient fresh water on the planet but due to bad economics, poor infrastructure, inadequate water supply, sanitation and hygiene, there is a limited water supply which can be useful to people. At the current time two billion people are living with a rick to reduction of access to freshwater resources and by 2050, one in four people at least are likely to be affected by shortages of fresh water. Countries are facing a span of water concerns, such as enlarging water scarcity, water-related calamity, insufficient access to safe and clean water, and cross-border management of water. Water pollution is getting worse, and water resource governance structures are fragile and fragmented [20]. The Freshwater reservoir is also under pressure from agriculture, industry and growing population. The change in climate is leading to more constant and extreme weather events leading to an increase in levels of water pollution, scarcity, and flooding. In brief, the world is not on the path to succeed in the Sustainable Development Goal (SDG) on clean and safe water. The advancement in decreasing water pollution and reduction in water wastage is going to play a vital part in achieving this goal of SGDs.

Challenge 7—Modern Energy

Enlarging energy access to the rural population extends a critical challenge for its government. The existence of people without access to electricity and billions who depend on biomass for cooking specify both the non-fulfillment of past policies and plans in the world. A Country may look towards energy tests on three fronts, the existence of majority energy poor needing access to modern energy bearer [21]; the requirement for expanding the energy system to fulfill the access space and fulfill the needs of a rapid-growing economy and the wish to partner with global economies in the attempt to mitigate the climate change threats. Starting from efficient energy advancement to production of energy from solar and wind, and attaching them to the smart area as well as storage, various possibilities are there for the modern energy programs to benefit from Industry 4.0 technology portfolio. The industrial sector consumes a lot more energy than any other industry, using 54% of the worldwide delivered electricity. Factories and plants naturally are absorbing and wasting tons of energy so the management of output and usage could have returned cost exceptionally. This is where industrial IoT, can have a wide much influence on the modern energy program.

Challenge 8—Sustained Economic Growth and Productive Employment

The annual GDP growth declined from being 4.4% in 2000 to 3.2% in 2017. Globally, 61% of total workers were involved in informal employment in 2016 out of which the 10% were from the agriculture sector. The global unemployment rate was 5.6% in 2017 down from 6.4% in the year 2000, the decline has reduced to 5.9% since 2009. Compare to adult youth are three times more likely to suffer from unemployment, with the global unemployment rate of 13% in 2017. Poverty elimination is only possible through steady and well-paid jobs. Decent work means a platform for everyone to get jobs that is productive and output a equal income, safety in the work environment and social security for families, nice tools for personal advancement and social integration. It is also crucial that all women and men are given equal participation in the workplace [22]. Providing young generations the best platform to transition to a decent work calls for investing in education and training of the maximum possible quality, giving youth with skills that match labor market need, providing the way to social security and basic services irrespective of their contract type, so that every aspiring youth can attain the advancement in employment.

Challenge 9: Sustainable Industrialization, Innovation and Infrastructure

This is a tricky concern. Sustainability Development is based on these three inter-related terms—Infrastructure, Industry, and Innovation. In some low income based African countries, the infrastructure constraints reduced the businesses productivity by around 40%. Also, 2.6 billion people in developing countries lack access to constant electricity. One challenge is the requirement to increase Internet access by micro and SMEs in growing countries, particularly LDCs [23]. More than four billion people still lack access to internet, 90% of them being from the developing country. Another issue relates to in sufficient transport, which leads to greater trading costs, reduced export competitiveness, and decrement in attraction for foreign direct investment (FDI), mainly in landlocked developing countries (LLDCs). Overcoming this issue needs, moving cooperation, multimodal transport, transport gallery, and systematic transit methods. In addition, imperfect access to infrastructure, mainly for transportation, electricity, and energy, hinders growth, diversification and value increment in agriculture and agro-industry in rural areas. In developing countries, rarely 30% of products produced from agriculture undergo industrial processing, compared to 98% of products from high income countries.

Challenge 10—Reduce Inequality

It is well known that the income inequality is on the boom with the richest earning up to 40% of the total global income while the poorer earning only between 2 and 7% of total global income. If only growth of population is considered then 11% of inequality have increased in developing countries. These disparities are a widening call for a action that require some adoption of sound policies to uplift the bottom percentile of income earners and enhance the economic inclusion of all despite of any comparison between sex, race or ethnicity. Till now technology has been shamed for growing inequality. Income and wealth inequality is increasing in most countries worldwide today. It calls for nations to decrease inequalities in income, as well as those relying on age, gender, disability, ethnicity, race, origin, caste or economic or any other status within a country [24]. Income inequality is a worldwide problem which requires a worldwide solution. The Goal also aims inequalities among countries, adding that related characterization, and calls for the facilitation of synchronized and secure migration and movement of people.

Challenge 11—Make Cities and Human Settlement Sustainable

Around 75% of the total world's population now live in urban areas and by 2050 this figure will rise to 95%. Thus, sustainable development is difficult to achieve without transforming significantly the way we develop and manage our urban spaces. In 1990, there were 10 million inhabitants with 10 mega cities but in 2014 there are 453 million inhabitants with 28 mega-cities. This rapid growth of cities in the developing world, along with the increase in rural to urban migration has led to rise in mega cities. National and city governments find difficult to accommodate the rising population in the urban spaces and hence, the poverty must be concentrated to extreme in these areas. Industrial age over the past 300 years has made people settlements unsustainable, or unlivable. Centralized development has praised people to cover in small areas in creating and crafting towns and cities. Air pollution, water pollution and soil pollution raised by the industrial economy have left the cities with a toxic environment. To allow persons with different disabilities to live freely and participate equally in all face of life, States Parties shall take proper steps to ensure to persons with different disabilities way, on an equal aspect with able one, to the outer environment, information, transportation and communications, and other facilities and services enabling to the public in both areas rural as well as urban. These methods apply to, Buildings, roads, transportation Information, and communications.

Challenge 12—Sustainable Consumption and Production

Sustainable production and consumption are defined as the production and usage of products and services in a way that is socially profitable, economically feasible and environmentally kind over their life cycle [25]. The per capita material footprint increased from 5 metric tons in 2000 in developing countries to 9 metric tons in 2017 with the high use of non-metallic materials for infrastructure and construction. In 2002 in OECD countries the motor vehicle stock was 550 million out of which 75% were just personal cars. By 2020, the vehicle ownership is expected to increase by 32%. The households consume 29% of total energy contributing to 21% of CO_2 emissions. Every year about one third of global food produced is wasted which is equivalent to 1.3 billion tones while 1 billion people remain undernourished and the other 1 billion people go to bed hungry. The world's fresh water supply by means of rivers, lakes are polluted by the disposal of the industry waste into them and the rate at which the rivers and lakes are getting polluted is much faster than the rate at which the nature can recycle them and purify it to make it again usable by living beings. It is estimated that by 2050, the global population will reach 9.6 billion to meet the requirements of these many people almost three planets could be required to produce the natural resources to sustain the current lifestyles. Food loss and waste counts to a adverse misuse of resources, covering water, energy, land, labor, capital and needlessly eliminate greenhouse gas, affecting global warming and changing climate adversely. To ensure sustainable consumption necessary entails are needed to maintain the biophysical boundaries of the planet. And to reduce the global consumption rate to fit the biophysical capacity of planet that will produce well sustainable ecosystem services and benefits from them.

Challenge 13—Combat Climate Change

Climate Change is the major issue of our time and we are at a critical moment. Every country on every continent is now affected by the change in the climate. The average global temperature increased by 0.85 °C from 1880 to 2012. With each 1° of increase in temperature, there has been decline in grain yields by 5%. Due to warmer climate the Maize, Wheat, and other major crops yields have experienced a significant reduction worldwide of 40 megatons per year between the year 1981 and 2002. The oceans are getting warmer day by day, the amounts of snow and ice have significantly diminished. Due to warming and melting of ice the global average sea level rose by 19 cm from 1901 to 2010 as oceans expanded. From shifting weather representation that threatens food production, to increase in sea levels that maximize the risk of catastrophic flooding, the effect of frequent climate change is global in span and unprecedented in scale. Given present concentrations and current ongoing emissions of thee greenhouse gases, it is estimated that the global temperature will exceed by 1.5 °C by the end of 2020 compared to the global temperature which was in the during the year 1850–1900. The average sea level rise is estimated as 24–30 cm by 2065 and 40–63 cm by 2100. Without any major action today, adapting to these impacts in the upcoming years will be more difficult and costly.

Challenge 14—Conserve and Sustain Seas, Oceans and Marine Resources

Oceans, seas and marine resources forms a crucial component of the Earth's ecosystem and are essential to sustainable development. They cover almost more than two-thirds of the earth's area and contain 97% of the planet's water. Nearly 65% of the earth's surface is covered by oceans, generating half of the air we breathe with the production of 16% animal protein. In addition, oceans are important for worldwide food security and human health. Over three billion people worldwide depends upon marine and coastal resources, generating numerous jobs in various fields such as tourism, fishing, shipping and bio technology. However, marine ecosystems are currently being much threatened by the human activities. Oceans also play significant part in worldwide development which can help fight the poverty. Our oceans are unaware of the any kind of political or international borders, thus the issues related with the oceans and coastal must be deal internationally with a collaborative strategy. The efforts by just one individual company to prevent ocean pollution or preventing marines will have only small effect if others are not equally contributing to any solution, to have adverse impact there is a need of a solution which have simultaneous universal commitment. It is the time when our governments, the companies and we citizens realize, how important our oceans are and accordingly take actions to enhance and protect our marine and coastal areas and seas in order to continue the benefits both the intangible and tangible from them by enabling, supporting and improving the conditions of these areas.

Challenge 15—Increase Sustainability of Ecosystem, and Biodiversity

Biologically diverse ecosystem served by World Bank provide valuable economic services in countries. The term ecosystem introduced in 1935, describe the entire system of living organisms and abiotic factors such as water, air and minerals covering the given space. However, the way in which the species interact with one another and with the environment led to the concept of ecosystem management which includes four principles. The first is to protect entire habitats and their individual species. The second principle talks about maintaining the native ecosystem within each region. The third principle deals with management for resilience to disturbances and the last principle focuses on establishing buffer zones around core reserves. The growing awareness was that the extraction of the resources led to accelerate the biodiversity loss and degradation of ecosystem.

The association between biodiversity and ecosystem functioning has raised as a central challenge in ecological and environmental sciences. Community and ecosystem ecology provide two views on complex ecological systems that have increasingly complementary strengths and weaknesses. Combining the two perspectives are mandatory both to ensure continued scientific increment and to provide society with the scientific way to face growing environmental issues.

Challenge 16—Build Peaceful and Inclusive Societies
The progress in promoting peace and justice, building effective, accountable and inclusive institutions within the regions remains uneven. Due to increase in the violent conflicts in recent years, there has been highly increase in the armed conflicts which is causing the civilian casualties in a very large number and forcing millions of people to be away from their home. Moreover, the countries which has higher income rate are more intend to suffer from violence compare to the countries which has low income rate also they are more prone to corruption. The crucial relationship between peace and development has long been declared by the international community, but it is only with the acceptance of the 2030 Agenda for Sustainable Development, that peace and security issues have become fully integrated into the worldwide development agenda, at both the levels, policy as well operational level. Although "terrorism" counts for only a minimum percentage of the total number of brutal deaths, its events have increased steadily over the past decade. It recognizes that "there can be no sustainable development without peace and no peace without sustainable development."

Challenge 17—Foster Global Partnerships for Sustainable Development
A successful Sustainable development requires partnerships between the society, private sector and the government. Urgent action is required to mobilize, redirect and transform the power of private resources to meet the sustainable development objective. The people worldwide are more interconnected than ever before. The access to technology and knowledge can provide a good platform to share ideas and foster innovation. A main shortcoming of the present global partnership is the absence of accountability of stakeholders. The issue of today and the transformative change requirement to achieve sustainable development will need collective action from all countries based on their respective capacities worldwide. This Global Partnership focuses to be an inclusive, comprehensive platform that will equally support all sustainable development stakeholders. New technologies allow exciting new techniques for citizens and their organization to grow and use data in a democratic and effective manner. The Global Partnership can present them with a technique for both navigating through and profiting from the Data Revolution.

4 The Triple Bottom Line of Sustainable Development

The Triple Bottom Line concept is developed by John Elkington in mid 1990s. To support sustainability Triple Bottom Line (or otherwise noted as TBL or 3BL) can be an important tool by aiming at the comprehensive investment results based on the performances for People, Profits and the Planet. The accounting framework, called "the bottom line (TBL)," is related with either "profit" or "loss" generally at the bottom line of the revenue and expenses statements [26]. TBL framework can also be used by an organization to create higher business value. It is an accounting framework consisting Planet or Earth or Environmental, Profit or Financial and People or Social or community. The bottom line for environmental is the practice of the Company's work with the intent of increasing the benefits to nature and not reducing or destroying the environmental things. Managing energy consumptions is the practice which benefits the nature at very large amount. There are many other practices available which can help the nature and can be done easily includes reduction in waste and avoiding the use of endangered resources. Once such a process can be "Cradle to grave" which is a life cycle assessment of products.

Thus, having reduced, reused and recyclable approach. The bottom line for social is that it deals with the intent of providing the benefits of business to the labor and the community. Fair trade agriculture uses fair trade method that is an arrangement designed to help producers in developing countries achieve trading conditions. Fair salaries to all and not exploiting child labor are one of the key practices done. There are many other practices available for labors as safe work environment and suitable working hours. The bottom line for economic is that it deals with the economic value associated with the organization irrespective of the cost of all inputs.

4.1 Calculation of TBL

In general, the trick is not in defining TBL but how we can measure it. The TBL measures different dimensions including social welfare, environmental damage, counting endangered species, measuring performance between companies, etc. There is no such universal standardized way for evaluating [27] the TBL as, finding a common unit of measurement is one such challenging task in measuring the TBL. Use of prices and use of index are the two Approaches can be followed as a common measure of the unit. Prices can be associated with many products based on that we can measure whether that is in the bottom line. But, the technique of finding the correct price for any product is still a problem. Another solution can be to make use of an index, eliminating the incompatible units' issue via allowing the use of universally accepted accounting method. Even in this approach question may arise. For example, how to weight the various components of the index? Can we assign the equal weight to components as well as the sub-components? A better solution can be to make use of the TBL framework adopting the requirement of a different individual, programs, policies, geographic circumference, etc. The TBL can accommodate these differences. The TBL applications which include business, governments are convinced by the principle of economic growth, environmental development, and social sustainability, but the way in which they are measured can be totally different. Let us see the parameters associated with these three:

Measuring Economic Prosperity When the economists study the growth of economy, its focus is mainly on the income. The most common and acceptable measure of income worldwide in the gross domestic product (GDP). The GDP measure the value of all goods in the market and the services associated with that in any country in a year. It deals with the flow of money in the business world and the greater long-term profitability [28]. For measuring prosperity, one good starting point can be diving the GDP by the number of people in country without the distributional considerations. For example, the income of an individual, increment in a job, churn establishment, sector revenue, taxes paid etc.

Measuring Environmental Quality It deals with measuring natural resources availability [29, 31]. For example, consumption of energy, fossil fuel, water, management of waste, concentrating nitrogen oxides and sulfur oxide, greenhouse emissions, use of industrial recycled material, public transport ridership etc. To incorporate the air, water quality, the toxic waste and consumption of energy.

Measuring Social Capital and Equity Include measurements related to social dimensions of community or region. For example, poverty, rate of unemployment, the female labor participation rate, population percentage, household income, Charitable contributions, Average working hours of an employee, crime statistics, the mortality rate of infants, ownership of the home, voter participation, etc.

These can be variables for measuring the education, health, quality of life and social capital of the community. These are the challenges for putting the TBL into practice, which if measured properly can be beneficial to sustainability for a truly long-run perspective.

Shortcomings of TBL

Despite many advantages associated with the use of TBL many people still disagree with the way, TBL enhances the Sustainability conditions and its measurement. There are many reasons for this disagreement by the people—Applying TBL in the practical world is a big task. TBL doesn't talk anything about the Time dimension that is whether the current value is preserved while measuring the TBL or not. Difficult to measure planet, people and accounts in terms of a common unit as mentioned by TBL that is profit or cash [30, 32]. Adding all three together is quite complex. Difficulty in achieving the global agreement on policies incorporated by TBL.

5 Industry 4.0 Solution to Sustainable Development Challenges

As now we aware of numerous challenges which are making it difficult for the sustainable development which included—Hunger, poverty, inclusive and lifelong learning, scope of targets, lack of controlling power, lack of understanding and of the targets, low quality prioritizing, lack of governmental capacity, good health and well-being, ranked education, gender fairness, life on land, life underneath water and so on. The challenges for achieving these goals and targets are trusted to be too optimistic, or just too infeasible for the duration of time as the goals are extremely wide in scope and are required to take greater actions. For example, if we want to know, How any city in specific country functions? This simple question gets very difficult due to the lack of unstructured or abundant data within the country or globally. As even for planning properly and correctly there is need of citizen's involvement without which it's impossible to achieve the targets. Its indeed an urge to overcome all these challenges as without this it's impossible to achieve the goal of sustainable development.

Industry 4.0 provides many solutions to overcome and deal with all the problems mentioned above. The fourth industrial revolution is dependent on a combination of ten technologies, these technologies could be used to overcome the challenges and issued faced by sustainable development. Possible Practical Industry 4.0 Solution—For supporting farmers' industry 4.0 technologies like sensors, drones, micro-robotics [33] etc. can be used to produce the food in a more precise manner, designing export-oriented manufacturing works in developing countries, already increasing the number of works is being taken care by robotics. Also, tools like drones based surveillance helps in providing real-time data to support the management and maintenance of forests, protections from deforestation, and maximizing afforestation and reforestation. Virtual and Augmented reality (VR, AR) couples with smart phones to reduce poverty, increase production capacity, remote employment. Irrespective of leaving rural areas, human will be allowed to participate in fruitful activities worldwide in operating semiautonomous fruitful machinery by immersing in the augmented reality environment also have the potential to maximize the effort of fishing and control unauthorized fishing activities. IoT-enabled hardware can make the adequate impact with regards to savings and storing. Additive manufacturing, software, AI and 3D printing, can help reduce wastage, and emission could be reduced. Smart phones can be used to train the people to increment their income level, have the probability to enable growing countries to increase innovation resulting in their economies much efficient and productive. Data analytics, smart vehicles, and simulation tool strengthening the supply chain, increasing the estimation of demand in supermarkets, hotels, and enlarging food packaging industry could help to decrease the amount of food loss and waste, lowering the emission from transportation. Other tools such as by adopting smart water policy and programs, the opportunities to develop profitable means for lowering water pollution and wastage is incremented, innovative ideas to manage urban traffic [35]. The use of Nano technology [36], fog computing [34] and various technologies in food harvesting, distribution and processing has much potential to lower this wastage. Advancements are being done in creating solar and wind as the relevant electrical energy sources.

5.1 Industry 4.0's Economic Dimension of Sustainability

It is very crucial to oversee innovation investments for existence of an organization to adapt to great challenge, requesting clients, decreased lead times and requirement for huge adaptability existing in the present organization's condition. Industry 4.0 guarantees self-ruling creation frameworks in smart manufacturing plants bringing about expanded efficiencies. Machine, man and assets can legitimately speak with one another, products know and are smart enough to assess as to how they will be produced and the entire worth chain is coordinated. To accomplish this imagined future condition of the manufacturing or designing environment, customary industry needs to embrace an organized change program while Industry 4.0 progress has numerous specialized, affordable, authoritative and lawful difficulties. A powerful administration of task details to embrace those difficulties in the Industry 4.0 transition can be a key activity for the upcoming achievement of an organization [34, 36–38].

In the present worldwide environment, competitive benefit and sustainability of organizations depend for the most part on the ability of adjustment to changing organization prerequisites. The Industrial revolution, more specifically, Fourth Industrial Revolution, leading from the progressions in new digital innovations that is generally referred as industry 4.0, has been significantly changing dynamics of various organizations [39]. Mechanization of business forms together with development of novel plans of action imposes new digital expertise requirements for work. Developing future workforce involves not just drawing in and creating new ability required, yet in addition re-skilling current workers by preparing programs as well as re-planning work processes for diminishing the skill mismatch between occupations and representatives [40].

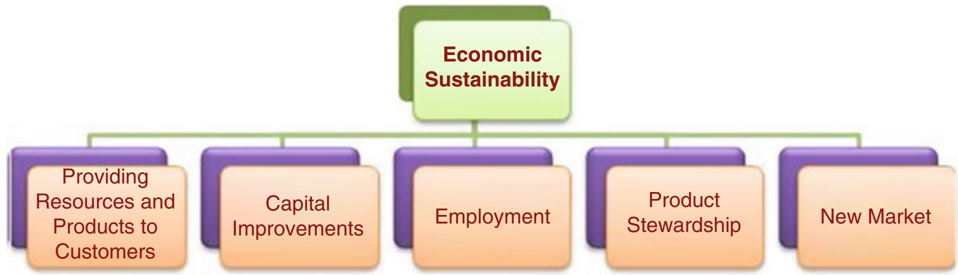
Economic Sustainability can be defined as the capacity of an economic system to generate a constant and improving growth of its economic indicators. The economic pillar of sustainability is where most businesses feel they are on firm ground. A business must be profitable, to be called sustainable. Contrary to what some people might believe, economic pillar is not about profitability at all. Activities that fit under economic pillar includes compliance, proper governance and risk management.

Economic growth is the process of exploitation of natural resources with the aid of available technology. Economic development is the outcome of economic growth. The economic dimension of sustainability tells us about the capability of an organization to sustain the populations by using the right mix of resources, while at the same time generating economic growth i.e. income and employment. It makes sure that the economic graph of the company is an upwards one. The economic dimension of sustainability assesses the impact an organization has on the economy of its stakeholders and the society. It keeps a check on which direction the company is heading and at what pace. The organization in order to be economically sustainable needs to maintain the quality of its products and services. Either the organization is product based or service based, it must keep their customers satisfied so that the customers always come back wanting for more.

Figure 5 represents the dimensions of economic sustainability. The economic dimension does not focus on the financial status of the organization. It focuses on these four material aspects:

1. ***Economic Performance***—Information regarding the generation and distribution of direct economic value is known by this aspect. Various economic indicators are utilized in order to measure the efforts of organization for a sustainable growth. Financial implications of the organization's growth on the society and the climate are also assessed. If the results of this assessment are not up to a certain predefined threshold value, changes are made in the organization to meet the predefined demands of the company.
2. ***Market Presence***—Market presence of an organization is defined as the share of the market held by that organization [41]. The larger the share, the more will be the capacity to grow. This aspect also assesses that how many senior management individuals were hired from the local community at significant level of operations. It also keeps a check on the standard entry level wage for all genders.
3. ***Indirect Economic Impacts***—An organization's economy has various effects on its environment and the society that we live in. The development of several large

Fig. 5 Dimensions of economic sustainability



infrastructures to support the economic development of the company may lead to climate change. Destruction of natural habitat in order to procure land and resources must be kept to a bare minimum and if possible, should be avoided at all costs [43].

4. ***Procurement Practices***—This aspect assesses the practices undertaken by an organization in order to obtain the right mix of resources required for proper functioning and growth of the organization. These practices must be applied keeping sustainability in mind. Depletion of natural resources in the name of progress is a step in the wrong direction as far as sustainability is concerned.

Based on the abovementioned points, it is safe to say that economy and sustainability deal with the same task: distribution of resources.

Economic pillar of sustainability is closely associated with the other two pillars of sustainability i.e. social and ecological. Economic sustainability is linked to the ecological dimension in relation to economical use of resource and energy and it is linked to the social dimension in relation to the creation and safeguarding of workplaces. The reasons that make it feasible for the corporations to come on board with sustainability strategies is the inclusion of profit and economic pillar. A counterweight in extreme measures is provided by the economic pillar because of which the organizations are sometimes pushed to adopt, such as abandoning chemical fertilizers or fossil fuels instantly instead of that phasing in changes [42, 47].

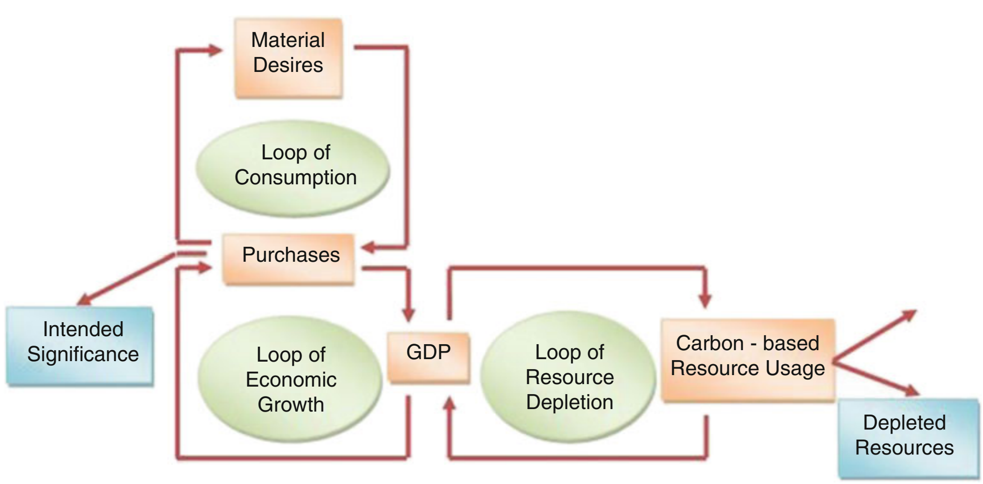
There are various sustainability challenges in the economic domain of an organization such as lack of understanding of goals, overly optimistic targets and low-quality prioritizing among many others. The possible solution to these problems could be given by Industry 4.0's elements such as robotics, virtual prototyping and big data analytics [44].

The bottom line when it comes to the economic dimension of sustainability is that this dimension is necessary for limited and constructive use of resources at hand. There lies an interdependence of growth loops in industry as shown in Fig. 6. The resources are finite and therefore sustainability is the need of the hour. The goal from an economic point of view is the sustainable growth of a company which in turn leads to positive impacts on the local, national and global economy. Under economic sustainability, an organization's wealth and revenue are better managed and invested. All these practices result in the organization being better equipped to tackle sustainability challenges which is a necessity in Industry 4.0.

5.2 Industry 4.0's Social Dimension of Sustainability

Social dimension of sustainability states that a sustainable business should have the support and approval of its

Fig. 6 Interdependence of growth loops



employees, stakeholders and the community it operates in. The main aim here is treating your employees fairly and being a good community member, both locally and globally [46]. It is a simple fact, if the employees are kept happy and are provided with a positive work environment, the results will be fruitful. Similarly, if the community members are taken care of, they will always let your company feel welcomed.

Most companies today are starting to understand the importance of the social pillar of sustainability, even more so after the advent of Industry 4.0. Earlier, companies did not invest in measures that would ensure employee satisfaction and happiness. But it was soon realized by companies that the more content the employees are, the better will be their productivity. On the employee side, the company focuses on engagement and retention strategies. They provide the employees with various benefits such as long maternity and paternity leave, flexible working hours, the prospect of working from home, bonuses for overtime or exceptional work and various learning and growth opportunities.

On the community side, the companies have turned to philanthropy to enhance their image among the people. The companies help the locals in fundraising for various events happening in the locality. They also provide sponsorship at various university and school level events. These companies adopt several NGOs and take full responsibility for their development and care. They provide scholarships to the underprivileged children so that monetary matters do not hinder their educational needs. And moreover, they also invest in local public projects.

On a global social scale, a company needs to be aware of how their products are being manufactured. What procedures are being followed every step of the way? Companies need to make sure that there are no ill practices going on to meet the requested demands. There could be serious consequences if an organization does not adhere with certain social guidelines and laws. For instance, let's say that some factories or outlets of a particular brand have hired children to carry out the work at that place. This is illegal and highly unethical. Such practices must not be supported. In fact, steps must be taken by all the big conglomerates in collaboration with various NGOs and federal agencies to stop such practices at a global level. Child labor is only one such practice [47]. There are many others such as corruption at workplace, money laundering, racketeering etc. The social pillar is against all such practices and not only condemns it but provides measures to eradicate it completely.

Other than ensuring that there are no malpractices going around under their noses, the companies must ensure the happiness and safety of the people that work for them [41]. In today's corporate scenario, this is easier said than done. The workload is immense, the working hours not flexible at all, the competition among peers is cutthroat to say the least and the pay in some cases is barely enough to sustain a living. In these circumstances, special measures are needed to be enforced to make sure that the employees are feeling secure and are motivated enough to keep working there while at the same time maintaining a balanced and healthy lifestyle. Measures such as overtime pay, bonuses, monthly reward system, a greater number of holidays, deserved promotions and many others can be implemented to serve the purpose of keeping the employees content [44].

One methodology that has proved itself to be effective in increasing the contentment level of employees is "work from home". It is also commonly known as laptop lifestyle. The employees are free to work from wherever they are comfortable working from. It is not essential to report to the office daily if the work assigned to that employee is being completed within the specified deadline. Obviously, this is only limited to companies dealing in IT and software solutions.

Another issue other than the happiness of the employee is of their safety. This is very essential especially in the case of factory workers. They must be provided with the appropriate safety equipment. Stabilized designing processes are supported by Industry 4.0 which leads to a continuous throughput and positive digital management of processes. The stability generated by the digital management of the operations provides well improved and suitable working conditions and a safe manufacturing environment for the employees. It is true that with the Industry 4.0's arrival, a lot of jobs will be handled by machines that were previously handled manually. With the advancement in technology and use of complete system automation, the human factor will be minimized [41]. This can be seen as a potential drawback of Industry 4.0 in terms of strengthening the employment rates but the quality output produced by an Industry 4.0 system will more than make up for the loss of manpower. In traditional organizations, various tasks concerning safety issues are performed in order to prevent the operational risks and safety hazards at the business level. It is however believed that the environment of new Industry 4.0 is about to be a new revolution in safety management practices with "out of the box" thinking.

Industry 4.0's pillar of social sustainability shown in Fig. 7 teaches us to care about the community we live in and the people that work for us. The term Social Sustainability can be understood as the capability to guarantee welfare in terms of security, health, education etc. and that too equitably shared among social classes and gender. Social Sustainability, specifically within a territory denotes the ability of the different stakeholders or social actors in terms of interacting efficiently, aiming towards the same goals, getting encouraged by the close interaction that happens at the Institutions, at every level.

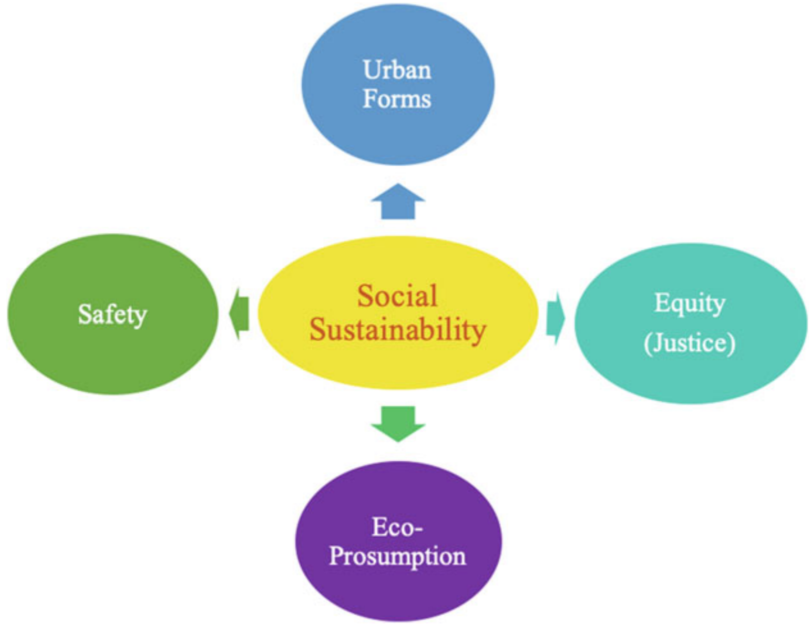


Fig. 7 Social sustainability categories

5.3 Industry 4.0's Ecological Dimension of Sustainability

Ecological Sustainability is the capability to preserve the following central functions of environment over time:

- Resource supply function
- Waste receiver function
- Direct usefulness.

To put it other way, within a particular region, environmental sustainability can be defined as the ability to improve the significance of environment while making sure that the renewal and the safety of environmental patrimony and natural resources is being considered as shown in Fig. 8. It is believed that Industry 4.0 provides a way of well-organized resource allocation including energy, water, raw materials and various other goods. This pillar of Industry 4.0 focuses on the capacity to utilize natural resources without disturbing the integrity and equilibrium of ecosystems.

The ecological pillar is often the most talked about. It is what comes to most people's minds when they hear the word sustainability. It is very easy to imagine and visualize the true meaning of sustainability in terms of our environment because it is all around us and people can relate to it in a way which is not possible with the social or the economical pillar. Industry 4.0 practices are designed in such a way that minimum amount of resources is required for the functioning of the company.

Nowadays, the focus of companies is on decreasing their use of water, carbon footprints, packaging waste an overall effect on the environment. It has been realized by companies that their positive impact on the planet will eventually lead towards a positive financial impact on themselves [34]. For instance, reduction in the amount of packaging material will decrease the overall spending on the products. This type of thinking is essential for all companies to have. Ecological sustainability can be achieved only if all the companies, whether large or small, adhere to certain guidelines relating to sustainable use of resources. The main task of this pillar of Industry 4.0 is that non-renewable resources must be substituted by renewable resources and renewable resources should only be devoured to the level to which they could be regained [38]. At present speed of depletion of natural resources, in 53 years our planet will run out of oil, natural gas in 54, and coal in 110. The fossil fuels that originated in

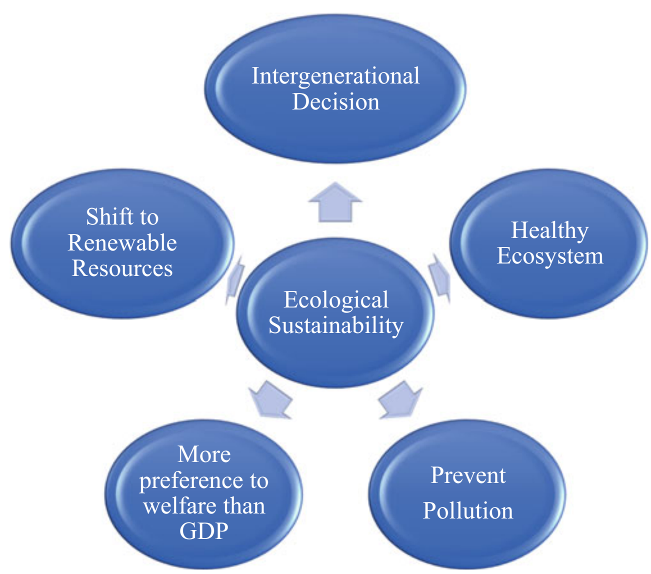


Fig. 8 Ecological sustainability

around 550 years ago had been consumed only in 200 years after their descovery. This is a stigma for the society that we live in today and we all must share it equally. We have no choice but to shift from non-renewables to renewables such as wind, solar, hydropower, biomass etc.

There are companies that have an obvious and undeniable environmental impact, such as production of food or mining. This type of companies is to be heavily blamed for the degradation of the environment. They tend to approach the ecological pillar through reduction and benchmarking. The fact that the impact of a business is often not fully priced is a major challenge to the ecological pillar. Simply put, there are externalities which are not being properly captured. The total cost of carbon dioxide, wastewater, land reclamation and waste in general are difficult to be calculated. Reason being, it is not the case always that companies are the ones on the hook for the waste produced by them. This is the place where benchmarking plays a role in trying to quantify such externalities, in order to track and report the progress of reduction in a better way.

Industry 4.0 practices minimizes the amount of waste generated and holds the company accountable for the waste they produce. It is the company's moral obligation to guide that waste in such a way that it does not harm anyone including people, wildlife, marine life and the natural vegetation's. The basic feature of Industry 4.0 is the use of emerging technologies and innovations for the reduction of pollution, greenhouse gas emissions, consumption of natural resources and waste generation and to accomplish various other ecological goals.

Emerging technologies and innovations offer an unparalleled chance to completely align environmental goals and business. For years, most of the corporations had the thought that improving the substructure and protecting the environment were contradictory objectives. This cannot be the case any longer. With the advent of Industry 4.0, business, environmental and social goals can be achieved all by following the same path. It is a path of advanced technologies and human-machine interactions. The technologies in Industry 4.0 possess the full capacity of making the existing process of production ecologically sustainable [37, 42].

The greediness of big companies and their negligence towards the environment has led to the rapid depletion of non-renewable resources. It has also caused the depletion of our forests in order to find land for construction and also to get wood as a resource [44]. Furthermore, it has led to the degradation of aquatic life as well as wildlife due to dumping of waste material. These companies when questioned about such practices, lie through their teeth and their highly qualified and heavily paid legal team handles the rest. This type of behaviour needs to be corrected right away if we want to have a better and sustainable future.

In Industry 4.0, companies should aim to be ahead of the curve and to put into action technological innovations which could improve sustainability as well as business performance. If they do so, a better brand status and a competitive edge would follow automatically. Improving the business sustainability and bottom line can be completely synchronized. The efficiency of resource usage can be very much exploited through closed loop supply chains with, re-use, recovery and re-utilization [31, 42]. The use of renewable sources of energy as their main power source by companies will go a long way in securing a better future for the next generation. If ecological sustainability becomes a competitive edge among companies, then it could be a boon for all of us. It is the guarantee of Industry 4.0 and its emerging technologies.

6 The Future of Sustainable Development

The future of sustainable development has begun to open through the opportunities provided by Industry 4.0. Sustainable development is here to stay and it is the need of the hour. An ethical and political principle forms the basis of the notion of sustainable development. The principle infers that the economic and social dynamics of present economy is compatible with the capability of natural resources to reproduce in an indefinite manner and up gradation of life conditions. The pursuit of the idea of sustainable development is totally dependent on the ability of government to promise an inclusive interaction of society, economy and environment as shown in Fig. 9.

The complete supply chain of a business which includes the requirement of answerability from primary level, from suppliers to retailers is encompassed by sustainability. When production of goods in a sustainable manner is seen as a competitive edge by multinational corporations then this vision has the potential of reconfiguring many supply chains which were based on only cut-rate production. Certainly, that picture is completely dependent on whether corporations really intend to clasp sustainability or it is just a humbug when they talk about it.

Let us take an example to illustrate how sustainable development has started to unfold with the advent of Industry 4.0. A machine learning algorithm which was developed for data collection and analysis has been successful in the identification of a sex trafficking ring. These results were achieved by a PhD student, Rebecca Portnoff. For doing so, machine learning algorithms were used to track bitcoin transactions. This is clearly resonant with the sustainable development goals. The complete potential of this work is yet to unfold.

Another instance of Industry 4.0 is the artificial intelligence system which is already improving human lives by improving their health. It diagnoses heart diseases and providing an estimate of patient's health condition in future. It has been done using augmented reality. Data is collected from a large number of patients; data patterns are discovered.

Fig. 9 Three pillars of sustainability

Based on these patterns, predictions regarding a patient's health are made which further enables the doctors to prescribe the appropriate treatment for patients. Hence, patients get an improved chance of living a long and healthy life. This system can be extended to a broader span of health problems.

At present artificial intelligence is also assisting the predictive policy framing for law enforcement to deal with crime. If developed efficiently, such systems can help police to act and stop a crime before taking place. Crime centers based on big data can also be established to make such systems more effective. This, as the cited article discusses, lowers restitutions and crime rates, and keeps communities calmer and safer. Further, predictive policing—in software's such as PredPol or HunchLab, use various metrics and differing approaches to reach the same goal, and this means that there is still wide field for evolution. As of late, predictive policing is starting to be used internally, with bigger integration. instead of like a third-party software—like it has so far. This suggests not only its advancements, but also developments of new features, such as software tactics suggestions and further Industry 4.0 upgrades.

Government is taking steps to get their systems and institutions ready for cloud to get benefitted by the revolution of Industry 4.0. Cybersecurity is one of the most important aspect in which governments are eager to exploit vast opportunities provided by Industry 4.0. Governments are aware of the possible risks associated with cloud computing. Therefore, many preventive measures are being adopted and undertaken as a component of this complete shift.

When sustainable development presented itself as a new paradigm for civilization, none took it as an easy target to accomplish. Also, no one suspected that it would be very complex to take true steps forward towards the purpose. Many approaches have been tried such as independent commissions, mega-conferences, campaigns, broad scientific assessments. And, progress has been witnessed and that too very heart-warming in some areas. To get a better assessment of what will be the ecological impact of Industry 4.0, appropriate methodologies should be incorporated. For example, material intensity [44, 45], life cycle assessment or energy accounting [30].

Overall, it can be said that Industry 4.0 is the tomorrow for many, if not all aspects of life which includes the goal of sustainable development. Many doors, linking the rising potential of technology and human innovation could bring about infinite chances for growth and triumph in realizing the goals set by humanity. The future has already begun to evolve speedily, involving many aspects of life and presenting more signs of arriving future.

7 Conclusion

The Sustainable Development Goals provide a set of qualitative objectives, providing a framework for both local and national governments to work in a common direction. The five P's of sustainable development—people, planet, prosperity, peace and partnership covers all the aspect for maintaining the sustainable relationship between the economic, social and ecological system. The sustainable development looks into 17 major challenges which focus on ending poverty by allowing all the people to have income above the poverty line, fighting hunger so that everyone at least able to earn three times meal, ensuring healthy life by providing measure to fight HIV/AIDS and other harmful diseases, facilities for inclusive and lifelong learning with the help of rapid advancement in technology, achieving gender equality by emancipating women and girls with education, expertise in skills and job, clean, pure accessible water by decreasing the water pollution and reduction in water wastage, enlarging energy by production of energy from solar and wind, sustainable economic growth and productive employment by providing decent work platform, Sustainable industrialization, innovation and infrastructure, reducing inequality in income and wealth as well as those relying on age, gender, disability, ethnicity, race, origin or caste, making cities and human settlement sustainable, production and usage of products and services in a way that is socially profitable, economically feasible and environmentally kind over their life cycle help in achieving sustainable consumption and production, combat climate change, conserve and sustain seas, oceans and marine resources, increasing sustainability of ecosystem and biodiversity, building peace and inclusive societies and foster global partnerships for sustainable development. The ten technologies of industry

4.0—sensors, drones, micro robotics, virtual and augmented reality, additive manufacturing, data analytics, cyber security, cloud computing, and IoT provide efficient solution to the challenges faced by Sustainable development.

References

1. Baldassari, P., & Roux, J. D. (2017). Industry 4.0: preparing for the future of work. People & Strategy, 40(3), 20-23.
2. Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). Industry 4.0: The future of productivity and growth in manufacturing industries. Boston Consulting Group, 9(1), 54-89.
3. Ustundag, A., & Cevikcan, E. (2017). *Industry 4.0: managing the digital transformation*. Springer.
4. Zhong, R. Y., Xu, X., Klotz, E., & Newman, S. T. (2017). Intelligent manufacturing in the context of industry 4.0: a review. Engineering, 3(5), 616-630.
5. Lanting, C. J., & Lionetto, A. (2015, November). Smart Systems and Cyber Physical Systems paradigms in an IoT and Industry/ie4. 0 context. In 2nd International Electronic Conference on Sensors and Applications. Multidisciplinary Digital Publishing Institute.
6. Bahrin, M. A. K., Othman, M. F., Azli, N. N., & Talib, M. F. (2016). Industry 4.0: A review on industrial automation and robotic. Jurnal Teknologi, 78(6-13), 137-143.
7. Nayyar, A., Jain, R., Mahapatra, B., & Singh, A. (2019). Cyber Security Challenges for Smart Cities. In Driving the Development, Management, and Sustainability of Cognitive Cities (pp. 27-54). IGI Global.
8. Singh, P., Gupta, P., Jyoti, K., & Nayyar, A. (2019). Research on Auto-Scaling of Web Applications in Cloud: Survey, Trends and Future Directions. Scalable Computing: Practice and Experience, 20 (2), 399-432.
9. Tofail, S. A., Koumoulos, E. P., Bandyopadhyay, A., Bose, S., O'Donoghue, L., & Charitidis, C. (2018). Additive manufacturing: scientific and technological challenges, market uptake and opportunities. Materials today, 21(1), 22-37.Wehle, H. (2016) Augmented Reality and the Internet of Things (IoT)/Industry 4.0.
10. Solanki, A., & Nayyar, A. (2019). Green Internet of Things (G-IoT): ICT Technologies, Principles, Applications, Projects, and Challenges. In Handbook of Research on Big Data and the IoT (pp. 379-405). IGI Global.
11. The Economist (2017) The world's most valuable resource is no longer oil, but data. The Economist, May 2017.
12. Lee, J., Kao, H. A., & Yang, S. (2014). Service innovation and smart analytics for industry 4.0 and big data environment. Procedia Cirp, 16, 3-8.
13. UN General Assembly (2015) Resolution adopted by the General Assembly on 25 September 2015.
14. Singh, Z. (2016) Sustainable development goals: Challenges and opportunities. Indian Journal of Public Health, 60 (4), pp. 247-250.
15. Beckerman, W. (2002). A poverty of reason: Sustainable development and economic growth. The Independent Institute.
16. Belahsen, R. (2014). Nutrition transition and food sustainability. Proceedings of the Nutrition Society, 73(3), 385-388.
17. Pandey, B. D. (2015). An Appraisal of the Global Warming: Problems Issues Corrective Measures. *Bonfring International Journal of Industrial Engineering and Management Science*, *5*(4), 133.
18. Pal, J. (2003). The developmental promise of information and communications technology in India. Contemporary South Asia, 12(1), 103-119.
19. Johnsson-Latham, G. (2007). A study on gender equality as a prerequisite for sustainable development. Report to the Environment Advisory Council.
20. Rijsberman, F. R. (2006). Water scarcity: fact or fiction?. Agricultural water management, 80(1-3), 5-22.
21. Carney, D. (1998). Sustainable livelihoods. Sustainable Livelihoods: What contribution can we make.
22. Anker, R., Chernyshev, I., Egger, P., Mehran, F., & Ritter, J. A. (2003). Measuring decent work with statistical indicators. International Labour Review, 142(2), 147-178.
23. Liedtke, C., Baedeker, C., Hasselkuß, M., Rohn, H., & Grinewitschus, V. (2015). User-integrated innovation in Sustainable LivingLabs: An experimental infrastructure for researching and developing sustainable product service systems. Journal of Cleaner Production, 97, 106-116.
24. Doyle, M. W., & Stiglitz, J. E. (2014). Eliminating extreme inequality: A sustainable development goal, 2015–2030. Ethics & International Affairs, 28(1), 5-13.
25. Tukker, A., Charter, M., Vezzoli, C., Stø, E., & Andersen, M. M. (Eds.). (2017). System innovation for sustainability 1: Perspectives on radical changes to sustainable consumption and production. Routledge.
26. Hammer, J., & Pivo, G. (2017). The triple bottom line and sustainable economic development theory and practice. Economic Development Quarterly, 31(1), 25-36.
27. Toth, F. L. (2003). Ecosystems and human well-being: a framework for assessment. Island press.
28. Bennett, M. I., & Giloth, R. P. (Eds.). (2012). Economic development in American cities: The pursuit of an equity agenda. SUNY Press.
29. A. Sharma, R. Ranjan, "Software Effort Estimation using Neuro Fuzzy Inference System: Past and Present" published in International Journal on Recent Innovation Trends in Computing and Communication (IJRITCC), ISSN: 2321-8169, Vol.5, Issue.8, Pp: 78-83.
30. Kumar, A., Sharma, A., Sharma, S., & Kashyap, S. (2017, July). Performance analysis of keyword extraction algorithms assessing extractive text summarization. In *2017 International Conference on Computer, Communications and Electronics (Comptelix)* (pp. 408-414). IEEE.
31. Costanza, R., de Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S. J., Kubiszewski, I., . . . & Turner, R. K. (2014). Changes in the global value of ecosystem services. Global environmental change, 26, 152-158.
32. Sridhar, K., & Jones, G. (2013). The three fundamental criticisms of the Triple Bottom Line approach: An empirical study to link sustainability reports in companies based in the Asia-Pacific region and TBL shortcomings. Asian Journal of Business Ethics, 2(1), 91-111.
33. Batth, R. S., Nayyar, A., & Nagpal, A. (2018, August). Internet of Robotic Things: Driving Intelligent Robotics of Future-Concept, Architecture, Applications and Technologies. In 2018 4th International Conference on Computing Sciences (ICCS) (pp. 151-160). IEEE.
34. Singh, S. P., Nayyar, A., Kumar, R., & Sharma, A. (2019). Fog computing: from architecture to edge computing and big data processing. The Journal of Supercomputing, 75(4), 2070-2105.
35. Das, S., & Nayyar, A. (2019). Innovative Ideas to Manage Urban Traffic Congestion in Cognitive Cities. In Driving the Development,

Management, and Sustainability of Cognitive Cities (pp. 139-162). IGI Global.
36. Nayyar, A., Puri, V., & Le, D. N. (2017). Internet of nano things (IoNT): Next evolutionary step in nanotechnology. Nanoscience and Nanotechnology, 7(1), 4-8.
37. Gebler M, Uiterkamp AJS, Visser C (2014) A global sustainability perspective on 3D printing technologies. Energy Policy 74:158–167
38. Joshi SC, Sheikh AA (2015) 3D printing in aerospace and its long-term sustainability. Virtual Phys Prototyping 10(4):175–185.
39. Ranjan, R., & Sharma, A. (2019). Evaluation of Frequent Itemset Mining Platforms using Apriori and FP-Growth Algorithm. *arXiv preprint arXiv:1902.10999*.
40. Brook JW, Pagnanelli F (2014) Integrating sustainability into innovation project portfolio management–a strategic perspective. J Eng Tech Manage 34:46–62.
41. Yung R, Siew J (2016) Integrating sustainability into construction project portfolio management. KSCE J Civ Eng 20(1):101–108.
42. Kumar, A., & Joshi, A. (2017, March). Ontology driven sentiment analysis on social web for government intelligence. In *Proceedings of the Special Collection on eGovernment Innovations in India* (pp. 134-139). ACM.
43. Sachin S. Kamble, Angappa Gunasekaran, Shradha A. Gawankar. "Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives", Process Safety and Environmental Protection, 2018.
44. Kumar, A., & Sebastian, T. M. (2012). Machine learning assisted sentiment analysis. In *Proceedings of International Conference on Computer Science & Engineering (ICCSE'2012)* (pp. 123-130).
45. Kumar, A., Khorwal, R., & Chaudhary, S. (2016). A survey on sentiment analysis using swarm intelligence. *Indian J Sci Technol*, *9*(39), 1-7.
46. Kumar, A., & Khorwal, R. (2017). Firefly algorithm for feature selection in sentiment analysis. In *Computational Intelligence in Data Mining* (pp. 693-703). Springer, Singapore.
47. Jain, D. K., Kumar, A., Sangwan, S. R., Nguyen, G. N., & Tiwari, P. (2019). A Particle Swarm Optimized Learning Model of Fault Classification in Web-Apps. *IEEE Access*, *7*, 18480-18489.

Saurabh Raj Sangwan is a research scholar in the Division of Computer Engineering at the Netaji Subhas University of Technology, New Delhi, India. He has completed his Masters in Software Engineering, [MTech (SWE), 2016–2018] from the Department of Computer Science and Engineering at Delhi Technological University, Delhi, India. He pursued his Bachelors in Computer Science and Engineering from DCRUST, Murthal, India. His research interests include intelligent systems, cognitive analytics and social web.

MPS Bhatia is a Professor in the Division of Computer Engineering at Netaji Subhas University of Technology, Delhi. He has been working with the University for more than 25 years. He is the Head of Training and Placement at the university. With an expansive teaching and research profile, Prof. Bhatia has guided many masters and doctorate students. He has presented several papers in international conferences and published work in peer-reviewed and science cited journals. His research interests include but not limited to Deep Learning, Cyber Security, Soft Computing, Social Media Analytics, Big Data Analytics, Knowledge Discovery and Software Engineering.

Big Data and Analytics in Industry 4.0

Abhilasha Sharma and Harsh Pandey

Abstract

The accelerating pace in change of information and communication technology has bring a phenomenal change in industrial environment. The induction of cutting-edge technologies leads to the transition in manufacturing processes that transforms the hand production methods into machine driven. This automation of manufacturing mechanisms results in industrial revolution. With the evolution of social web, the massive amount of data (big data) has been generated and its optimal utilization has contributed in shaping up the fourth industrial revolution. As a step towards the development of smart and sustainable industry, big data analytics is playing a critical role. The significance of big data on Industry 4.0 is exemplified by illustrating its use in research and practice.

Keywords

Big data analytics · Industry 4.0 · Smart manufacturing · Sustainable industry

1 Introduction

Over the past few decades, industries have continued to evolve and improve themselves by taking consecutive step by step growth owing to various industrial revolutions. From using steam power engines to electrical tools even further to automated machineries using computers. Human intervention has been reduced significantly by only providing commands as input to the computer for processing and handling machines. This very last level of interference is also going to be removed with the joint effort of Industry 4.0 and Big Data. Machines would be provided with enough data which will empower them to decide for themselves what would be their next step and a fallback mechanism which will notify the respective officers if things get wrong.

In today's business oriented competitive world, companies are facing challenges in utilizing big data to its full potential. Many manufacturing industries are not ready to cope up with such enormous data due to lack of reliable analytical tools. Companies need to rewire their entire framework to deal with such a huge data and get some insights out of it. Various limitations that exists [1, 2] are listed as (1) collecting and filtering high speed data generating from IOT devices (2) apply the suitable analytical model (3) installing smart IoTs devices (4) setting up cloud computing and data warehouses (5) skilled labor to understand and operate them (6) faster connectivity (7) faster processors (8) maintaining and supervising the entire interconnected automated system and so on. All this requires huge capital investment and time to be enforced properly. The world is also facing an acute shortage of data engineers and scientists for comprehending big data. So, the companies are trying to find solutions in other ways like giving the task of installing and maintaining this data to a third party which will also provide the needed business incentives or running campaigns and courses to train their employees etc. Currently, Japan is popularizing the idea of Society 5.0 which aims to solve problems by implementing solutions of industry 4.0. Canadian Government is trying to implement the blockchain in their system with Canada focusing on cyber physical system enabled manufacturing and service innovation [3], which proves that despite of the shortage of resources, the world is continuously moving forward.

The chapter try to explain the definition of industrial big data, its history and impact followed by swot and pest analysis, general architecture with various tools and techniques. It is concluded with the elaboration of sustainability achieved with big data and industry 4.0.

A. Sharma (✉)
Department of Computer Science and Engineering, Delhi Technological University, Rohini, Delhi, India

H. Pandey
Department of Electronics and Communication Engineering, Netaji Subhas Institute of Technology, Dwarka, Delhi, India

A. Nayyar, A. Kumar (eds.), *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-14544-6_4

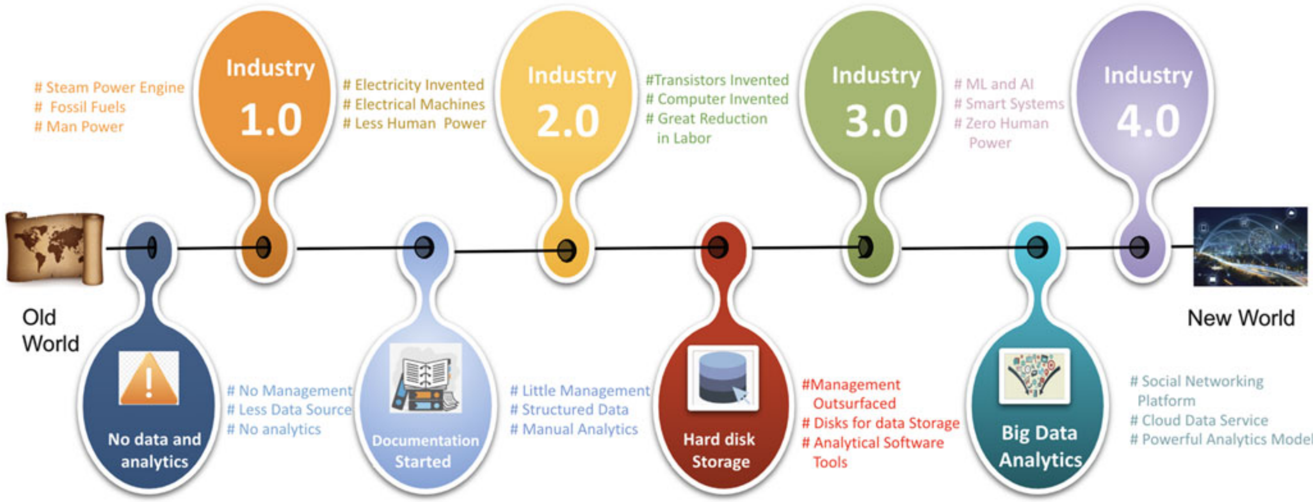


Fig. 1 Evolution of industrial revolution and big data

2 Big Data and Industry 4.0

The accelerating use of social networking sites [4] has been contributed towards the generation of a huge and massive amount of data named as *big data*. It is a large reservoir of data [5] comprises of messages, blogs, chats, documents, comments, pictures, web forums, online discussions, commercial transactions, machine generated web logs etc. It can be classified into different categories based on their source of generation such as personal big data (data generated through personal usage), social big data (data generated over social web), professional big data (data generated by officials) etc. Some of the popular real-time sources may include google search index, database of Facebook user profiles or the products displayed on any product-based website and so on. Industry 4.0 (fourth industrial revolution) [6] is an umbrella of various leading-edge information and communication technologies that helps in early defect detection and prevention which in turn increases quality, agility and productivity. Big data analytics has been identified as one of the significant components of industry 4.0 as it provides valuable insights for the purpose of smart factory management. This scenario requires the data to be processed with advanced tools and technologies in order to provide relevant information. The data that has been generated from the source of industries is call up as *Industrial Big Data*.

2.1 What Is Industrial Big Data?

The term industrial big data includes data that is generated inside industries by machines, mobiles, human-machine interfaces, surveillance cameras or Internet of things (IoTs) devices installed inside the plant, data on cloud, smart sensors data, cyber-based data etc. The term *Industrial Big Data* [7, 8] was first coined in 2012 along with industrial revolution 4.0, with the assumption that the data generated by industrial equipment might hold more important business values. As soon as a machine would generate data, it would be detected by a tracker and can either be sent to cloud for higher level analytics or can be stored in a database for future analytics. This processed information will be utilized for making better decisions, gaining insights and resource optimization [9–14].

2.2 Evolution of Industrial Big Data

With the evolution [15, 16] of industrial revolution, big data undergoes with different transformation phases. The mapping of different industry versions and big data analytics has been represented in Fig. 1.

The wave of industrial revolution started in 1760s with Great Britain [17] aimed to drive out the textile related work from homes and shops to industrial plants in order to make large number of units which would cost less and results in increase of profit and quality. This revolution [18] prompted people to migrate from the villages to urban area for work with the use of steam and water powered machines. All the data related to number of items made, cost and sell price, number of workers, their wages etc. were maintained on sheets by the officials but the flow was unstable and there were many loopholes in the system. Moreover, due to steam and water powered machines, plants were generally set up near rivers and canals.

Few countries like America and Europe started to follow the model of industrial revolution unfolded by Britain. Due to

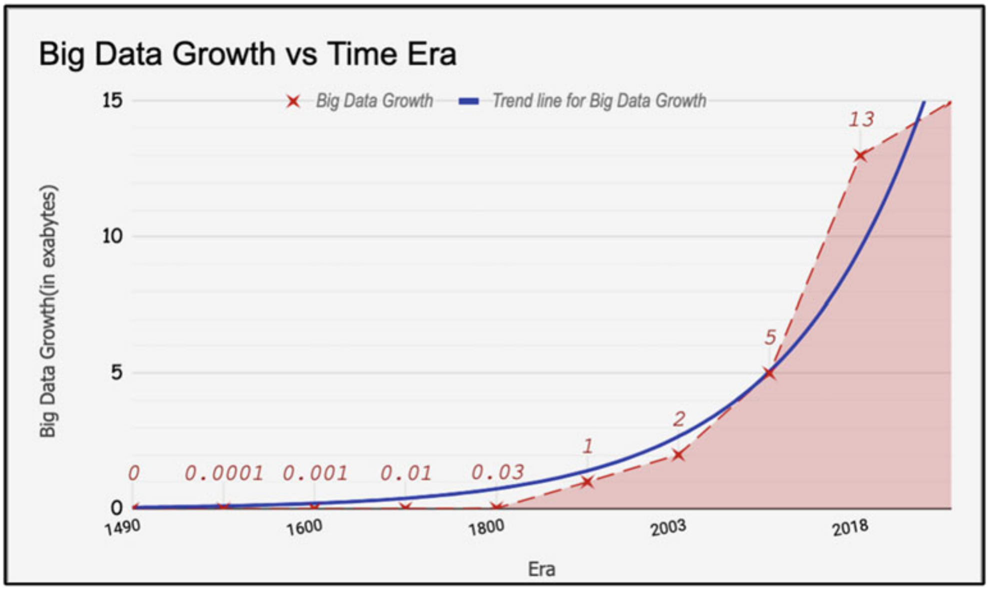


Fig. 2 Growth rate of big data vs. time

availability of natural resources and man-power America easily excelled in.

Next revolution [19] came in 1870s when electricity was discovered which in turn removes the dependency of water rich sites and plants, and they further can be set up close to the source of raw material. It also reduces the transportation cost. The invention of machines, assembly lines, introduction of division of labor strategy has greatly increased the overall throughput of the entire system. The living standards of human being has been dramatically changed and uplifts with the arrival of electric telephones, lightings, radios [20]. The social participation and interaction have been improved due to facilitation in worldwide connectivity. In all, the definition of social life took a huge turn. The creation of social data has been started but due to technical limitations this data couldn't be stored, not unless the invention of storage devices like disks, floppy, CDs, pen-drives, hard disks which marked the onset of Industrial 3.0. This era is also called as Digital Revolution [21] due to the development of computers, networks, web sites etc. Most of the manual work from the industries moved towards a few lines of code automating most of the processes. The process of data storage, creation of analytical software tools, data analytics has started in use not just on profit and loss but on everything [22] including type of location for plant, weather, raw material, transportation, market strategies, and much more. This was the beginning of industrial big data. Data has been shifted from mere piles of white papers to large storage devices for later analytics. This period also marked the beginning of neural networks for computation. In 1943, neurophysiologist Warren McCulloch and mathematician Walter Pitts wrote a paper on how neurons might work. They modelled a simple neural network using electrical circuits in order to describe how neurons in the brain might work. The effort to simulate a neural network continues to fail.

In the late twentieth century or the early twenty-first century, all the pieces for Industrial 4.0 started [23] to fall on right places. The development of television, cellphones, Internet of Things (IoTs) devices were on high pace. The first successful network was also trained, and the storage of data turned cheaper. Now the data created can be easily stored or analyzed. The recent industrial technology introduces the installation of surveillance cameras, interconnected IoT devices inside the plants. These devices will generate data that can be analyzed quickly and make real time decision [24] or can be stored for future analytics. In the twenty-first century, Industry 4.0 connects the IoTs with manufacturing techniques to enable systems for information share, its analysis and its use to guide intelligent and meaningful actions.

The graph in Fig. 2 describes the evolution of big data with time. There were only 5 exabytes of information created by the entire world from the start and the year 2003 and now the same amount is created in every 2 days. In 2011, the McKinsey report on big data states that in 2018, USA alone will face a shortage of 140,000–190,000 data scientist as well as 1.5 million data managers. Currently, every day 4 exabytes of data is produced, almost the same as the amount of data produced till 2003.

2.3 Impact of Big Data on Industry 4.0

The manufacturing industry [25] is most affected by big data trends and possibilities due to the nature and amount of data produced by it. Most of the manufacturers have just initiated the process to discover the potentials of using big data tools, but there are already few pioneers within the biggest manufacturers who have provided some big data uses cases [26, 27] to follow. Major impacts of big data have been listed below.

Risk Management

There are risks involved in industries when they change any of their business strategies or create a new product for whether it will be a success or failure. Earlier, there was no platform or tool to get some insight into it. Suppliers now have the choice to share their products data with their partners and customers which creates a complete transparency and a highly effective communication channel for both parties. This way the manufacturer can see exactly whether the supplier is delayed with production or just in time, to then adjust all the related processes and avoid waiting times. Quality data can also be shared in the same way; manufacturers can have all the production and product related quality metrics from their suppliers before even receiving the parts. By having greater visibility into supplier quality levels and other performance metrics, the manufacturer can have a clear visibility on their supplier portfolio and have insightful data in their hands when it comes to supplier contract negotiations.

Build-To-Order Configuration

Manufacturing ‘products to order’ became a trend and not just in the automotive industry but in aviation, computer services, and even consumer goods. The build to order (BTO) production approach is one of the efficient and profitable business models. But in order to view a real growth analysis from it, a well-defined data platform needs to be in place that analyses customer behaviour and sales data. The manufacturer needs to have access over all the sales related data and is able to perform precise predictive analytics to foresee order volumes on each possible configuration and adjust their supply chain accordingly.

Improve Product Quality

Product quality maintenance is a top priority for manufacturers. Most of them already have the data needed to significantly improve quality levels and reduce quality-related costs, but just few of them can connect their data sources in a way that it would provide actionable insights.

After Sales

The costs of warranties and recalls can easily go out of control even due to the smallest mistakes in the production process. With the help of big data, it is possible to either avoid or to foresee warranty or recall issues, potentially saving significant amount of money.

Daily Production Tracker

In order to optimize production quality and yield, manufacturers need to have a daily data flow from their production lines in order to see discrepancies and opportunities in real time. This includes sensor data coming from the production machinery and financial information that is properly linked together with operational data for analysis purposes. Employee data can also be tracked in real-time by allowing a data exchange between employee badges and production line units.

Data-Driven Enterprise Growth

By using big data, it becomes possible to quickly compare the performance of different sites and to pinpoint the reasons for the differences. In addition to internal production and sales data, it is also possible to analyse entire markets, build what-if scenarios and to use predictive models.

Predictive and Preventive Maintenance

When operational data is analysed with pattern recognition method, upcoming failures and need for maintenance can be predicted well in advance. This allows preventing downtimes and costs related to maintenance. At the same time, preventive maintenance will drastically prolong the lifespan of machines by preventing irreversible failures.

Overhead Tracking

The overhead cost is determining the profitability of each manufacturer. To have real control and visibility over these costs, big data environments are needed with connected data sources and advanced analytics capabilities. Part standardization is one of the major areas that can hugely contribute towards reducing supplier-related costs. It can reach a significant reduction in the part and supplier proliferation. This has not only saved cost but also time on managing parts data.

Testing and Simulation of New Manufacturing Processes

The day has arrived in manufacturing when no risk can be taken for implementing a new product or process. Both manufacturing processes and the products can be tested before production/implementation. This is possible due to digital twins, virtual reality environments and manufacturing process simulations. The use of such environments and tools can allow manufacturers to eliminate the risk from decision-making processes. The aim of this so-called digital transformation of manufacturing companies is to implement such data platforms that make strategic decision making a science.

Logistics

The usage of big data in logistics is less widespread than in other manufacturing areas. Warehousing and transportation

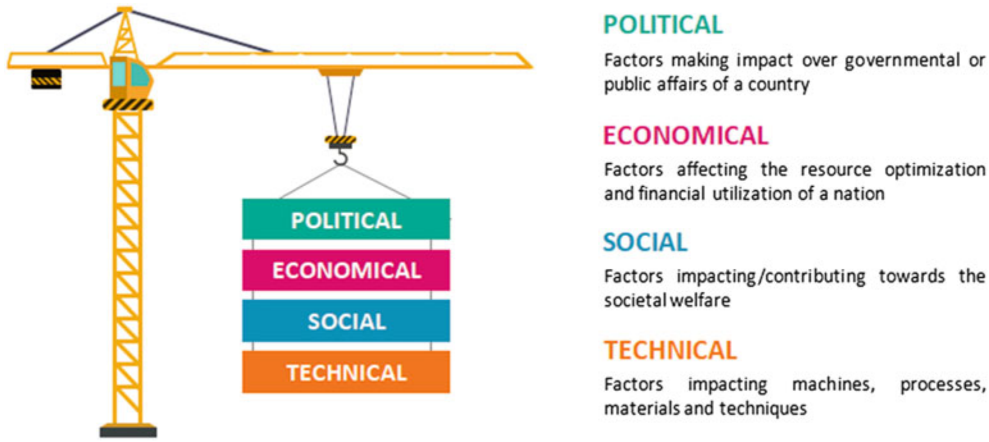


Fig. 3 SWOT and PEST—quality and performance assessment frameworks

are both areas where big data tools can be used with great Return on Investment but still there are only a few companies around the world who is operating data-driven logistic services.

3 Assessment Framework for Big Data Analytics in Industry 4.0

Assessment frameworks [28] are quality management tools used (a) to assess the existing performance of an organization and (b) to identify the needs and measures for its improvement. The goal is to provide a structured conceptual study of learning outcomes and a well-coordinated planning layout to meet the above objectives. This section paraphrases the two popular assessment frameworks for big data analytics in industry 4.0 namely, SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis and PEST (Political, Economic, Social and Technical) analysis. Figure 3 illustrates the definition of principal components of both the frameworks.

3.1 SWOT Analysis: Analysing Intrinsic and Extrinsic Factors

SWOT analysis framework used by industrial organizations as a strategic planning technique for analysing relevant internal and external factors making an impact over people, process, product, projects, initiatives, objectives, outcome of a system. It is a fundamental model used to evaluate the organizations internal strengths and weaknesses, as well as external opportunities and threats. It also acts as a vigorous mechanism for decision making. Figure 4 represents the SWOT matrix of big data analytics in industry 4.0 followed by brief explanation of its key characteristics.

Strengths

1. *Autocratic and independent operating system*
   Use of big data allows the operating system to take independent decisions in determining the most feasible and optimal algorithm through analysis of trends and patterns in previously stored data.
2. *Reduced errors due to reduced human intervention*
   Human errors evaded as the functionality of the industry depends solely on the analysis of data, rather than raw ideas from the human brain.
3. *Increased employment in the IT sector*
   Use of big data in industries expands the career scope for skilled computer engineers and data scientists and increases job opportunities.
4. *Competitive products*
   High quality products based on data collected from user/customer search trends are manufactured to ensure public acceptability of the product.
5. *High flexibility*
   Any change in the routine of the industry can be easily incorporated as no physical changes need to be made. Changes can be efficiently and conveniently incorporated by updating the data set that is fed into the algorithm used by industry 4.0 running on big data.
6. *Availability of real time data*
   Since industry 4.0 running on big data makes use of real time data, the products manufactured by the company are always in accordance with the market trends and can never become obsolete or outdated.
7. *Planning ahead*

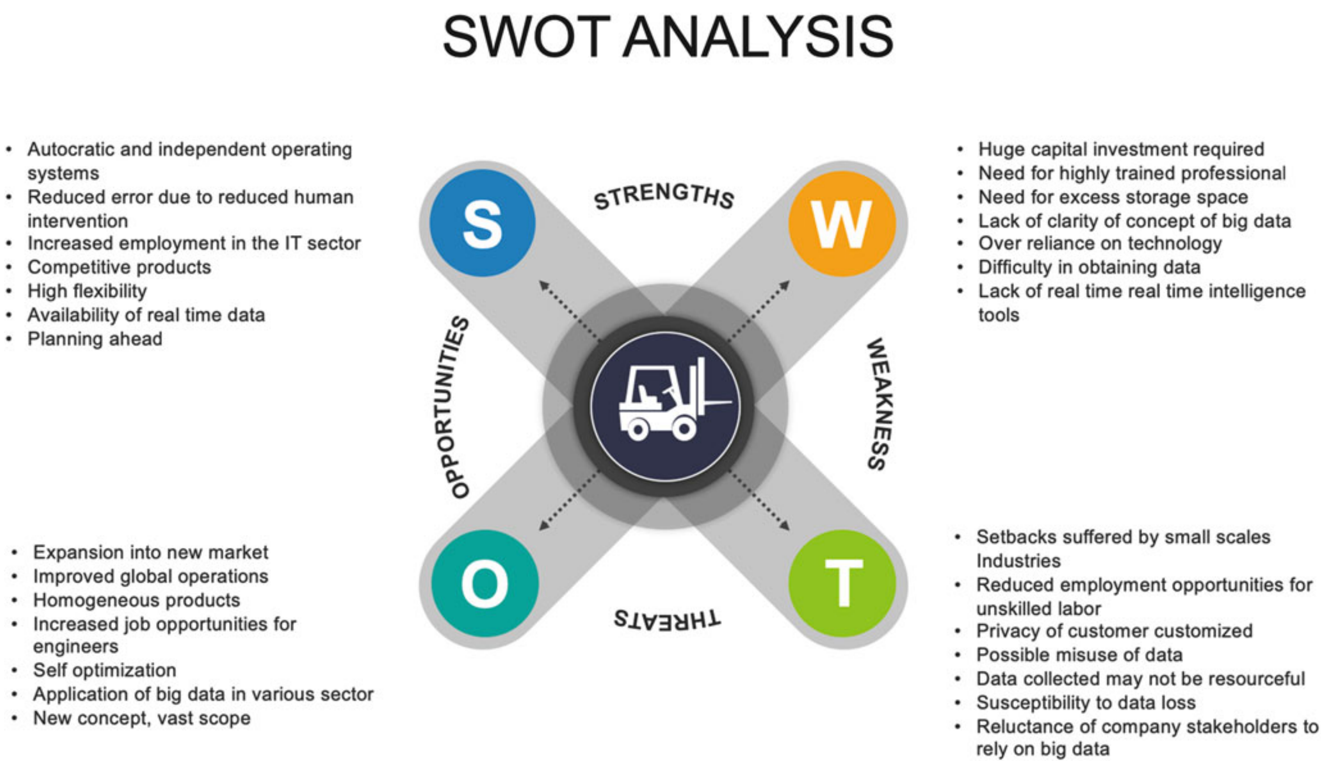


Fig. 4 SWOT analysis of big data analytics in Industry 4.0

Analysing patterns in previously acquired data allows future planning within the industry to increase profits and work efficiency.

Weaknesses

1. *Huge capital investment required*
   Large sums of money required for research and development to devise suitable algorithms that make efficient use of the available data. Further, automation of machines also involves huge expenses.
2. *Need for highly trained professionals*
   In contrast to unskilled manual labor in conventional industries, industry 4.0 necessitates the need for highly trained and intellectual professionals to operate machines running on big data.
3. *Need for excessive storage space*
   The accuracy of the results is directly proportional to the size of the data set used to obtain them. Therefore, to improve the accuracy, a large amount of data is needed and finding sufficient storage space is a difficult task.
4. *Lack of clarity of concept of big data*
   Being a relatively new discipline, very less work has been done in this field, rendering it difficult to become an expert in big data.
5. *Over reliance on technology*
   Industry 4.0 using big data requires computers for all jobs from data collection to data processing. Being entirely dependent on computers limits the imagination of humans and hampers their problem-solving ability.
6. *Difficulty in obtaining data*
   Not all data may be freely available on the internet. Some restricted data might be under the ownership of a few authorized personnel only and acquiring it may require legal permissions.
7. *Lack of real time intelligence tools*
   While data is available in huge volumes, this is not the case with the supporting tools and aids that are required to analyse data that will be used in industry 4.0. Currently, very limited tools are available than can handle real time data analysis.

Opportunities

1. *Expansion into new markets*
   Analysis of market trends allows the organization to expand its horizons and apply previously gained knowledge to new services.
2. *Improved global operations*
   Access to worldwide data gives insight into the requirements of customers of all regions, castes and communities. Customized products can be manufactured to suit the needs of each population to enhance global operations.
3. *Homogeneous products*
   Working on similar data sets will allow standardized processes for product development, consequently warranting uniformity in manufactured products.

4. *Increased job opportunities for engineers*
   With industries shifting to big data, the requirement for skilled engineers will exponentially increase, thereby leading to an upsurge in job opportunities for engineers.
5. *Self-Optimization*
   Gradually with time, the available data worldwide will keep on increasing. With increase in data, the accuracy of the results obtained through it will also increase. Therefore, big data analytics in industry 4.0 is a self-optimizing system that continually improves itself with the addition of new data.
6. *Application of big data in various sectors*
   Big data can be exploited for the growth and development of various sectors, such as banking industry, agricultural industry, sports industry, healthcare industry etc. where no such prior work has been done.
7. *New concept, vast scope*
   Since the concept of big data is yet to be properly established, only 0.5% data has been analysed worldwide. This leaves a lot of scope for the remaining data to be exploited for the benefit of the society.

Threats

1. *Setbacks suffered by small scale industries*
   Small scale industries may find it difficult to survive in the market while competing with large industries that can afford operations based on big data.
2. *Reduced employment opportunities for unskilled labour*
   Shifting to big data will almost completely exhaust the need for unskilled labour in industries as negligible manual work will be required.
3. *Privacy of customers compromised*
   To ensure public acceptability of products, buyer trends are carefully studied and analysed, often compromising the privacy of customers.
4. *Possible misuse of data by unauthorized personnel*
   Confidential data in the wrong hands could be a huge threat to the company as the entire industry runs on this data alone.
5. *Data collected may not be resourceful*
   For extracting patterns from data, huge amounts of data is required, all of which may not contribute to the result obtained. This non-resourceful data is nothing but a waste of storage space and processing time for the algorithm.
6. *Susceptibility to data loss*
   Over dependency on computers makes the organization's useful data prone to hacks, leaks and power outages, resulting in loss of important data.
7. *Reluctance of company stakeholders to rely on big data*
   Big data, being a relatively new concept, is often seen with skepticism. Stakeholders may be hesitant in investing in new technologies and may prefer traditional and established approaches.

3.2 PEST Analysis: Scanning Macro Environmental Factors (Fig. 5)

Political

1. *Intellectual Property Rights (IPR)*
   Intellectual Property Rights must be strongly enforced to protect the interests of individuals, as well as industries. This allows an organization to file a law suit against competitors trying to steal the company's data and seek legal help for the same.
2. *Government support and funding*
   Any business in its initial phase requires significant investment. However, since industry 4.0 running on big data is a relatively new concept, the Government might show reluctance in funding such a venture.
3. *Legal policies*
   Due to certain laws and regulations of the legislature, free data on a particular subject may not be available to a lay man. Only a few authorized personnel may be having the right to access and use certain data, which makes the process of big data collection complicated and time consuming.
4. *Government instability*
   With a change in the political power, various laws also change. Change in ownership rights of data or open availability of data might affect the functioning of an organization.
5. *Taxation policies and Regulatory practices*
   The big data industry will benefit from low taxation policies and lenient regulations. Such support from the Government will encourage industries to shift to big data and give a boom to the rising concept.

Economic

1. *Market Trends*
   Any fluctuations in the prices of products in the market will result in variations in the data set used in the industry.
2. *Cost of data warehouses*
   Storage cost for huge volumes of data is a major area of expenditure for industries running on big data.
3. *Monetary value of big data*
   Big data in its raw form has a lot of potential value that can't be quantized. Therefore, valuing this data is a complex, but crucial task as the market value of big data determines the investment an industry has to make to purchase it for its use.

Fig. 5 PEST analysis of Industry 4.0 using big data

4. *Investments and Capital*
   For a big data industry to run smoothly, investors must be made to realize the scope of big data and its prospective returns in the future, so that sufficient funding can be obtained.
5. *Business cycle*
   The ongoing phase in the business cycle directly affects the operations of an organization. Recession in the market will result in lesser profits for the big data industry.

Socio-cultural

1. *Employment of data scientists*
   Unavailability of data scientists due to lack of popularity of the concept of big data makes it difficult to find suitable employees to run such industries.
2. *Public acceptance of products*
   To ensure public approval of products, buyer trends are carefully studied and analysed so that manufactured products meet the needs of the customers.
3. *Environmental regulations*
   Norms concerning the environment directly affect industries using big data as such industries require huge data warehouses to store large volumes of data. Running these data centres require high electricity consumption.
4. *Population diversity*
   Miscellany in the population results in an unbiased data set. Diversity ensures that data from all age groups, regions, castes and communities is collected for use by the industry.
5. *Literacy*
   The level of education of the employees directly affects the company standards (highly intellectual data scientists are required to work on big data), while the education level of investors determines their inclination towards investing into an industry running on big data.

Technological

1. *Technical advancements*
   Progress in technology leads to convenience in tasks. Automated scripts to process big data according to the data set will avert the need to manually write algorithms each time.
2. *Research and Development*
   Being a new notion, big data analytics requires proper R&D. The pace and progress of research and development in big data will influence the success or failure of industry 4.0 using big data.
3. *Competing technologies*
   Big data in industries has not gained much popularity due to two main reasons- expense of acquiring data and lack of real time business intelligence tools. Rival technologies such as Spark, Storm and Data Torrent RTS are capable of providing solutions to these problems and thus pose a threat to big data analytics in industry 4.0.

4. *Supporting tools and aids*
   Without real time intelligence tools, big data is just huge heaps of irrelevant data. The success of big data analytics depends on the quality of the tools used to extract the results.
5. *Internet penetration*
   Due to the over dependency of humans on the internet, data sharing is becoming increasingly accessible, which means all kinds of data is easily and freely available for everyone online.

4 Data Analytics in Industry 4.0

The exponentially rising generation rate of data has made the big data analytics a challenging area of research. As the data generation is increasing day by day and the rate of analysis should be greater than or equal to the rate of data generation so that after analysis, there would be a threshold for detecting problems and to take the required actions simultaneously. This section describes a generalized architecture with deeper insights into the analysis part and about the emerging technologies that industries are opting to simplify the process.

4.1 General Architecture for Data Analysis in Industry 4.0

The analysis of high-speed real-time data from industrial equipment and IoT [29] devices is much harder by using the conventional techniques. Therefore, the problem lies in finding the correct data and process it. Earlier, in the absence of recent technologies such as IoT devices [30], faster network connectivity, cloud computing etc. the data was stored locally and analysed manually or with a prewritten static software that will fail to respond in case of improbable situations. With the inception of machine learning and artificial intelligence, models can be trained to respond even to the unexpected conditions to avoid higher risk and disaster situations. A well-defined system is necessary which will improvise on itself with time to come up with new upcoming challenges.

Table 1 illustrates the basic tools and technologies that are needed to implement for smart manufacturing in the industrial plants. A possible architectural journey of data [31, 32] from its generation by machines to its utilization in taking the right decision, has been described in detail. The functional flow diagram represented in Fig. 6 has described the journey of data. The entire processing of the system function is explained as follows:

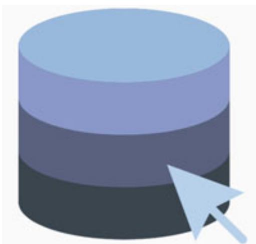
1. Data generated from the sensors is first normalized to a standard form because of different data formats. The normalizer block consists of different interfaces for each sensor. An interface will read the data and convert it. The conversion speed of normalizer should match the data generation speed to avoid any loss of data.
2. The normalized data is then stored in the databases. Local database inside plant and master database on the cloud is maintained for storage.
3. The data through the cloud is passed to the analytics block via the master database. This block consists of data pre-processing tools and a highly trained machine learning or artificially intelligent model whose output will drive the oncoming suggestions and steps.
4. The next block is a Data Transferring and Alerting System (DTAS). This is responsible for communicating the results to admin via SMS, app or website alerts.
5. The user-interface requires an admin to examine the results and take appropriate measures. Suggestive measures are provided by the DTAS where admin can choose solution to take or he can approach the problem in a different way if he has a better solution.
6. These decisions are employed in the simulation block and the stability of the system is monitored. The output of the simulation validates that the steps are safe and are taken to the production level. If somehow that step turns to be unstable, a new step is taken and simulated.
7. In case of decision failure, the data is sent back to the cloud where the model will be retrained to not perform this step again in future. This functionality is implemented in the correcting block.

4.2 Data Science and Machine Learning for Smart Manufacturing

Data science is a multidisciplinary [33] blend of *data inference, algorithm development, and technology* in order to solve analytically complex problems. It involves taking all the industry related data as input and find useful business level information. For example: a manufacturing plant can take a survey from the customer related to its product and can analyse the data to know the strengths and weakness in order to make changes for better customer experience which would ultimately turn profitable in the long run. Smart manufacturing can be done by using the data to check which areas to focus on and divert the production on that. It would make a cost efficient and profitable model.

Figure 7 shows the mini blocks that made up the whole analytics part. It shows that the data entering the cloud system undergoes data pre-processing [34] such as cleansing of data to remove unwanted noise and redundant data. The resultant data would be easy to analyse and interpret. The next step is feature extraction [35] which consists of selecting only the meaningful information out of the huge piles of data. This is a critical step

Table 1 Installations required in manufacturing plant for system architecture functional flow

Technologies needed	Description
Smart sensors 	These are the main data sources including devices for sensing temperature, speed, valve status, weights, cameras, etc. For instance, a temperature sensor will read the temperature of an operating machine relative to the threshold temperature of the whole plant. If the temperature is increasing, it will generate data which will trigger the system to make required adjustments. If the temperature gets too hot at once, it should not wait for the data flow and analysis, instead, it will send an alert to either shut the machine automatically or inform the operator to do so
Storage 	It includes setting up a local database at the plant and a master database on the cloud. The master database will be treated as the main reservoir of flowing data. The analysis will be performed on the master database. Data coming to the database is precious and should be protected at any cost. A local database is set up in the plant in case of network failure. It will act as a temporary reservoir at that time to prevent the loss of data
User-interface 	It includes apps, websites, and SMS which will notify the admin regularly about the health check of the entire plant. The results depend on the data analyzed, it can be a simple 'status: ok' message or an alert with suggestive measures to take
Simulation mechanism 	It consists of a virtual environment where possible steps taken by the admin or the automated system will be tested by considering the environment parameter same as that of the plant to verify if the steps are stable and safe to execute

because choosing the wrong features would result in poor model performance even if the pre-processing and training part is carefully done. Hence, most of the data scientists these days are focused on developing algorithms to extract the best features. Best features lead to best results. Using AutoEncoders and their hybrids, word count, creating a bag of words, ontologies, tf-idf, n-grams are some of the popular feature extraction processes. The next step involves training a model on the resultant features for finding patterns and make decisions. Data scientists primarily make decisions and predictions using predictive casual analytics, prescriptive analytics, and machine learning which are discussed as follows:

- *Predictive Casual Analytics*
  It includes predicting the possibilities of an event in the future. For instance, banks need to check the background of a person applying for the loan to make sure that they are going to get the money back.
- *Prescriptive Analytics*
  It includes making a model that is self-aware of its surroundings. The model will be capable to make intelligent decisions on its own. It not only predicts but suggests a range of prescribed actions and associated outcomes. Reinforcement learning comes under this.
- *Machine learning for making prediction and pattern discovery*
  Machine learning models are used for prediction and decision making. It consists of training a model with the predefined dataset to predict the trends in the future. It works by adjusting its weights according to the pattern it finds among the dataset. Table 2 lists a broad classification [36] of machine learning algorithms.

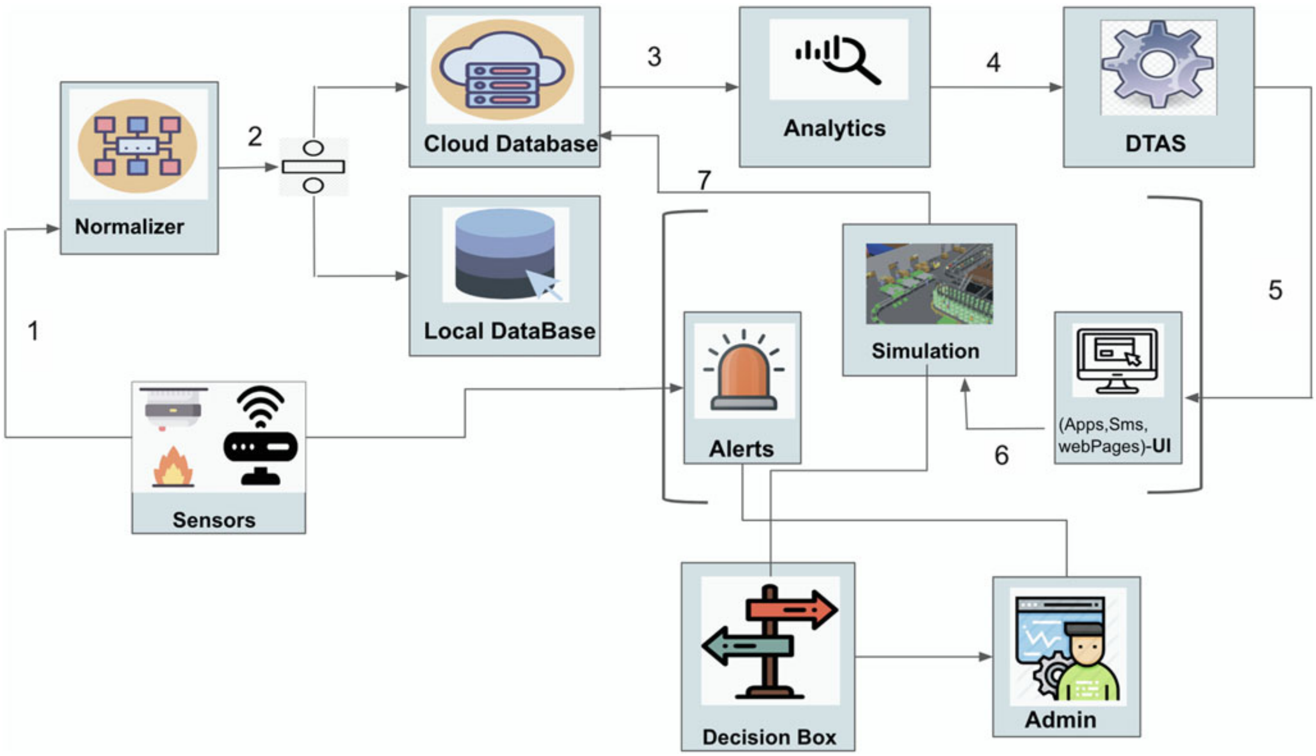


Fig. 6 System architecture diagram of data analysis in Industry 4.0

4.3 Big Data based Emerging Technologies for Industry 4.0

This section covers pre-existing and emerging technologies that can be employed in industrial big data to fully setup the sustainable environment of industry 4.0. They are represented in Fig. 8 and discussed as follows:

1. **Cyber Physical System**
   Cyber-Physical Systems (CPS) [37] are integrations of computation, networking, and physical processes. Embedded computers and networks monitor and control the physical processes, with feedback loops where physical processes affect computations and vice versa. The technology builds on the older (but still very young) discipline of embedded systems, computers and software embedded in devices whose principle mission is not computation, such as cars, toys, medical devices, and scientific instruments. CPS integrates the dynamics of the physical processes with those of the software and networking, providing abstractions and modeling, design, and analysis techniques for the integrated whole.
2. **IoT**
   Internet of Things [38], is a system of the interrelated network of mechanical and digital machines, computing devices, objects, animal, even human that are provided with a distinct identifier and used to transfer data over a network without the interaction of human-to-human or human-to-computer [39]. It has evolved from the triangle of wireless technologies, micro electromechanical systems, and the internet. It has enabled the unstructured machine-generated data to be analysed for insights for improvements [40].
3. **Cloud Computing**
   It is defined as providing of computing services [41–49] like servers, storage, databases, networking, software, analytics, intelligence and more over the internet, here

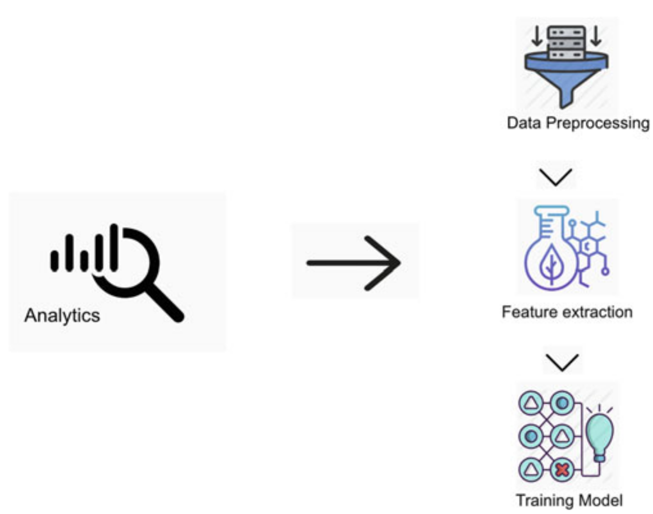


Fig. 7 Block diagram of big data analysis processes

Table 2 Classification of machine learning algorithms

ML algorithms	Examples	
Supervised	Regressors	Logistic, polynomial, support vector regression
	Classifiers	Decision Tree, Naive Bayes, Support Vector Machine, Deep Learning Algorithms like Artificial neural network
Unsupervised	Clustering	K-means clustering
	Association	Apriori algorithm, Eclat algorithm, FP-growth algorithms

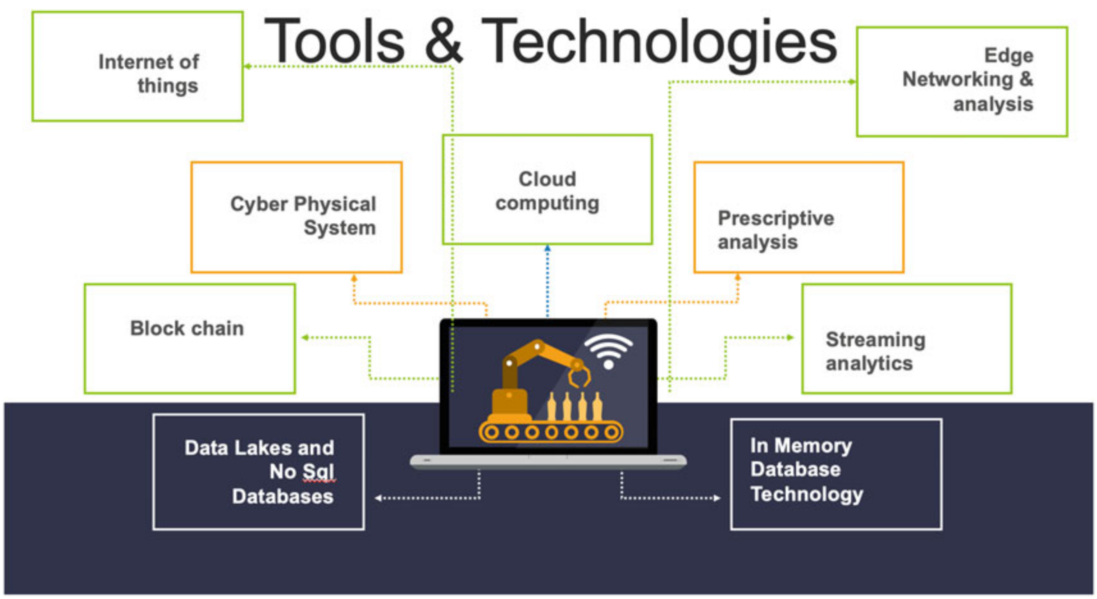


Fig. 8 Emerging tools and technologies for utilizing big data

cloud, to offer flexible resources, faster innovation and scalable and distributed system. It reduces overall cost, increases speed, productivity, performance, and security.

4. **Edge Networks and Analytics**
   It is defined as processing and analysis of data [50] near the generating devices instead of sending the entire blob of data over a network to a centralized database. Industries can filter out the data at the time of creation to send an analysis of only the useful data. Thus, reducing the operational cost and time. Edge analytics has gained quite an attention as the 'Internet of Things' model of connected devices has become more prevalent.
5. **Prescriptive Analysis**
   It is a domain of business analytics [51] which aims at finding the best course of actions for a given solution. It is a collaboration of descriptive and predictive analysis. Descriptive analysis means getting deeper and deeper insights about a situation based on the previously available data whereas predictive analysis refers to the forecasting of events in future by finding patterns in events that have already occurred and determining the chances of events that can occur.
6. **Streaming Analytics**
   also called event Stream Processing, is the analysis of large, in-motion data generated [52] as an action or set of actions, such as financial transactions, equipment failure, or some other trigger. These triggers are very minutes state changes related to a system at a point of time like—a click, sensor reading or some measurable activity. The growing IoT devices will immensely increase the amount of data that would be generated. Therefore, real-time data manipulation, normalization, cleansing, advanced analytics and pattern of interest detection would immensely reduce overall processing time and cost and would increase an industries potential. It's somewhat like edge analytics.
7. **IN Memory Database Technology**
   Large data is generally stored in hard drives and it is accessed from there to RAM whenever execution needs to be performed. IN memory [53] model will provide large RAM magnitude that saves the time for data transfer. Giant tech vendors like Microsoft, IBM, SAP, Oracle provides such technologies.
8. **Data lakes and NoSQL Database**
   Increasingly, industries are building data lakes for storing their vast data repositories [54] that are collected from different sources and storing it at single database for easy access by other domains. This is very different from the concept of data warehouse where the data stored is filtered and uniform. Due to large variance of data and

their inability to comprehend all at once, it's better to store unstructured data and process it depending on the use-case. Now, these unstructured data cannot be stored in relational database due to the organized structure of those databases. Therefore, NoSQL databases (like MongoDB) are required where it is easy to store data whether it is structured or not.

9. **Blockchain**
   Blockchain is a distributed database system [55] that acts as an open collection for storage and management of transactions. Each transaction record is called a block which contains the timestamp of the transaction and the link between the previous transaction, making it almost impossible for anyone to alter the data. Blockchain provides for the integrity of transactions but not for the analysis, this is where big data comes in. With this interlinked data as the source, models can be trained to identify the patterns in consumers spending habits and alert about the risky transactions.

5 Big Data as a Practical Solution Towards Sustainable Development

Big data and Industry 4.0 have the potential to shape up the industrial process in terms of resource consumption, process optimization, automation and much more. It can be inferred that it also plays a key role in achieving sustainable development. A detailed explanation of how these technologies can be used to attain sustainability in various application areas (represented in Fig. 9) are described as follows:

1. **Manufacturing Industry**
   Manufacturing industries can use big data applications in a variety of ways. It can use analytics to monitor and improvise. Big manufacturing plants create hundreds of thousands of mechanical parts every day. But the production process faces various challenges like sometimes the quality doesn't match up to the require mark, sometimes the wastage of huge raw material increases costing, sometimes the workers make unusual demands and stops working, affecting the overall productivity of plant and themselves, sometimes leakage of gases or poisonous things can have catastrophic effects, etc. All these problems can be solved with the powerful monitoring of advanced IoT devices. IoT devices like cameras with image recognizer, smell sensor to detect poisonous gases, weight and quality check sensors can be employed for such tasks. One the other hand, problems like creating strategies to increase overall growth and demand in the market can be solved by using big data which can improvise the system flows inside and outside the plant. Prescriptive analytics can come handy for these scenarios to create a solution keeping into account events of the past.
2. **Sports Industry**
   Sports is one of the leading industries urging people to make a career in it. Big data can help players train smarter and improving faster. Live streaming of a player playing game can be taken using camera which will capture the player's game from multiple angles, those clips will be

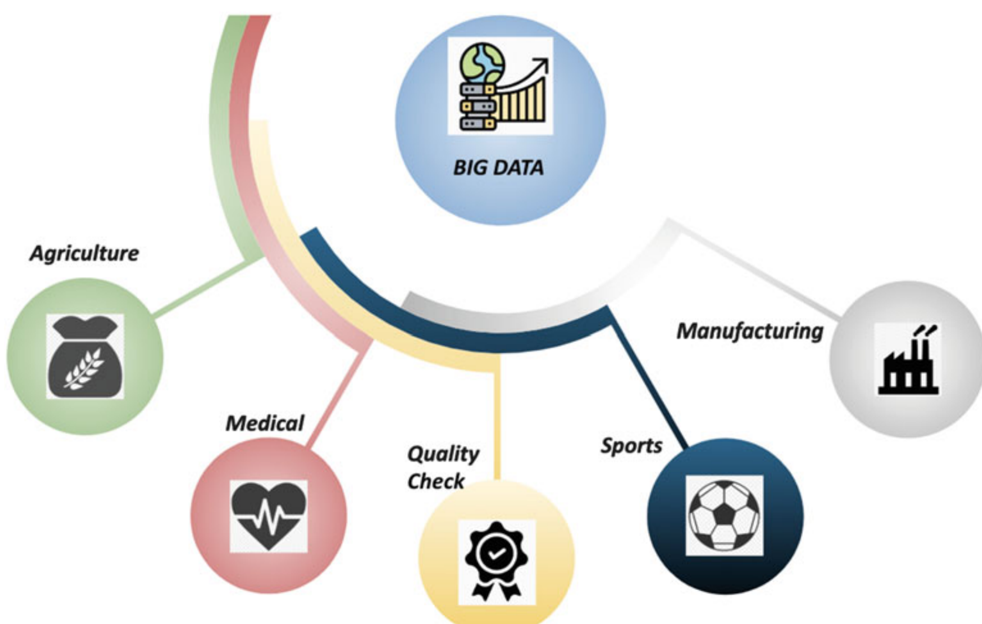


Fig. 9 Real time industries using big data

supplied to a model which will output the weak points for the player and will also provide him with the steps to improve. It will be much more efficient than human coaches. It will help a newbie to grasp the game more easily and efficiently. SciSports is a leading sports industry. Football analytics company SciSports has won a competition to see their football innovations become a reality. The firm uses data to assess the quality and potential of football players around the world to help with recruitment and transfers.

3. **Quality-Check Industry**
   These industries do not create any product; they give the validity of a product. One such example can be taken for the quality test of oranges using drop-test. In drop test, an easily compressible surface is created with a material of high elasticity, the oranges for testing can be dropped on this surface. The surface will be pressed depending on the firmness of oranges. If the orange is too loose, it will be pressed instead of pressing the surface. If the orange is too firm, it will press the surface, transferring the entire impact to the surface. Appropriate mechanical sensors can be embedded inside the surface to calculate the extent of compression, the compression data will be sent to a model along with other passive parameters which can determine the quality of the orange.
4. **Medical Industry**
   In the medical industry, big data holds a crucial role for the future. Human activities depend largely upon their mood, surrounding and health condition. Models can be trained to monitor the activities of human and find recurring patterns which may turn out to be a disease. IoTs devices and smartphones can be employed for that. These devices can help to track every day's human activities and transfer the data over a cloud to a model. The model can send alert to the person accordingly. Nowadays, IoT devices like smartwatches are available which are equipped with pulse rate sensors to check human health regularly. They send regular notifications to the user regarding the schedule for exercise, health-check-up's etc. Smart shoes are also developed which can fit the size of the wearer and make walking and running easier than before. Big data can also be used by hospitals to categorize the area of a city into zones. These zones are developed based on the medical emergencies needed in the past. The zone with higher emergency needs can be effectively monitored and given more facilities like more ambulances and more health centres.
5. **Agriculture Industry**
   Water level and nutrition level monitoring devices can be implanted in the soil to measure their real-time values. These devices will be equipped with the alerting system in case of water or nutrients level below a threshold value and notify the farmer accordingly. The overall values can be sent to the cloud where it can be inputted to a pre-trained model and sends the corresponding output to the farmer. It can also be made a closed loop system where triggers can be used by the model to automate the process of water and nutrients addition process. The amount of value to be added will be decided by the model. Hence, the overall system can be automated. These devices will also check the plant's health and can alarm the farmer when crops will be prone to disease or pests. It can also be used to check the overall state of the soil before growing a crop and decides the best-suited crop for that condition which will not only increase the overall productivity but also keeps the health of the soil constant. Growing the same type of crop repeatedly on a piece of land would result in depletion of nutrition level of the soil. Therefore, to avoid such deficiency farmers can use crop rotation technique where the next crop selection will not be done manually but a model will be trained on the values generated by these monitoring devices and decides the best next crop. The model will not only consider the nutrition and water level, but also keeps track of temperature, humidity, weather, and geographical location.

6 Conclusion

Big data clubbed with industry 4.0 is a revolutionary tool and its advantages are infinite as validated by the SWOT and PEST analysis. Automating tasks and implementing an optimized, secure architectural model will save resources for the next generation and make their lives more sustainable. It will take the world a step further into the future by removing the limitations of human activity. However, keeping pace with these technologies require an individual to be highly skilled and well knowledgeable in identifying and solving any real-time problem. Such problems can be as small as a minute shift in the data generated, which may affect their surroundings, even their lives later. Decrease in human intervention, requires him to be more vigilant and proactive.

References

1. Wollschlaeger, Martin, Thilo Sauter, and Juergen Jasperneite. "The future of industrial communication: Automation networks in the era of the internet of things and industry 4.0." *IEEE Industrial Electronics Magazine* 11.1 (2017): 17-27.
2. Kumar, A., & Sharma, A. (2016). Paradigm shifts from e-governance to s-governance. *The Human Element of Big Data: Issues, Analytics, and Performance*, *213*.
3. Lee, Jay, Hung-An Kao, and Shanhu Yang. "Service innovation and smart analytics for industry 4.0 and big data environment." *Procedia Cirp* 16 (2014): 3-8.
4. Weber, L. (2009). Marketing to the social web: How digital customer communities build your business. John Wiley & Sons.
5. Retrieved from the Wikipedia: https://en.wikipedia.org/wiki/Big_data
6. Retrieved from the Wikipedia: : https://en.wikipedia.org/wiki/Industry_4.0
7. The Rise of Industrial Big Data. GE Intelligent Platforms. 2012.

8. Kelly, J., & Floyer, D. (2013). The industrial internet and big data analytics: Opportunities and challenges. 2016-08-02]. http:// wikibon, org/wiki/v/The Industrial_ Internet_ and_ Big_ Data_ Analytics: _ Opportunities_ and_ Challenges. Wikibon.
9. Solanki, A., & Nayyar, A. (2019). Green Internet of Things (G-IoT): ICT Technologies, Principles, Applications, Projects, and Challenges. In *Handbook of Research on Big Data and the IoT* (pp. 379-405). IGI Global.
10. Nayyar, A., Jain, R., Mahapatra, B., & Singh, A. (2019). Cyber Security Challenges for Smart Cities. In *Driving the Development, Management, and Sustainability of Cognitive Cities* (pp. 27-54). IGI Global.
11. Das, S., & Nayyar, A. (2019). Innovative Ideas to Manage Urban Traffic Congestion in Cognitive Cities. In *Driving the Development, Management, and Sustainability of Cognitive Cities* (pp. 139-162). IGI Global.
12. Batth, R. S., Nayyar, A., & Nagpal, A. (2018, August). Internet of Robotic Things: Driving Intelligent Robotics of Future-Concept, Architecture, Applications and Technologies. In *2018 4th International Conference on Computing Sciences (ICCS)*(pp. 151-160). IEEE.
13. Nayyar, A., Puri, V., & Le, D. N. (2017). Internet of nano things (IoNT): Next evolutionary step in nanotechnology. *Nanoscience and Nanotechnology*, *7*(1), 4-8.
14. Puri, V., Nayyar, A., & Raja, L. (2017). Agriculture drones: A modern breakthrough in precision agriculture. *Journal of Statistics and Management Systems*, *20*(4), 507-518.
15. Retrieved from the Wikipedia: https://en.wikipedia.org/wiki/Industrial_Revolution
16. Blinder, A. S. (2006). Offshoring: the next industrial revolution? *Foreign affairs*, 113-128.
17. Ashton, T. S. (1997). The industrial revolution 1760-1830. *OUP Catalogue*.
18. Deane, P. M. (1979). *The first industrial revolution*. Cambridge University Press.
19. Mokyr, J. (1998). The second industrial revolution, 1870-1914. *Storia dell'economia Mondiale*, 219-45.
20. Atkeson, A., & Kehoe, P. J. (2001). *The transition to a new economy after the second industrial revolution* (No. w8676). National Bureau of Economic Research.
21. Rifkin, J. (2012). The third industrial revolution: How the internet, green electricity, and 3-d printing are ushering in a sustainable era of distributed capitalism. *World Financial Review*, *1*(1), 4052-4057.
22. Greenwood, J. (1997). The third industrial revolution: Technology, productivity, and income inequality (No. 435). American Enterprise Institute.
23. Bloem, J., Van Doorn, M., Duivestein, S., Excoffier, D., Maas, R., & Van Ommeren, E. (2014). The Fourth Industrial Revolution. *Things Tighten*.
24. Li, G., Hou, Y., & Wu, A. (2017). Fourth Industrial Revolution: technological drivers, impacts and coping methods. *Chinese Geographical Science*, *27*(4), 626-637.
25. Shrouf, Fadi, Joaquin Ordieres, and Giovanni Miragliotta. "Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm." *2014 IEEE international conference on industrial engineering and engineering management*. IEEE, 2014.
26. Retrieved from the https://www.actify.com/industry-topics/10-big-data-use-cases-manufacturing/
27. Retrieved from the https://www.scnsoft.com/blog/big-data-in-manufacturing-use-cases
28. Retrieved from the https://www.visual-paradigm.com/guide/strategic-analysis/utilizing-the-various-strategic-analysis-tools/
29. Wan, Jiafu, et al. "Software-defined industrial internet of things in the context of industry 4.0." *IEEE Sensors Journal* 16.20 (2016): 7373-7380.
30. Gilchrist, Alasdair. Industry 4.0: the industrial internet of things. Apress, 2016.
31. Hermann, Mario, Tobias Pentek, and Boris Otto. "Design principles for industrie 4.0 scenarios." *2016 49th Hawaii international conference on system sciences (HICSS)*. IEEE, 2016.
32. Wang, Shiyong, et al. "Implementing smart factory of industrie 4.0: an outlook." *International Journal of Distributed Sensor Networks* 12.1 (2016): 3159805.
33. Data Science Retrieved from the https://en.wikipedia.org/wiki/Data_science
34. Pandey, H., & Sharma, A. (2018). Social Big Data Analytics Using Sentiment Learning Algorithms for Smart Cities. *International Journal of Information Systems & Management Science*, *1*(1).
35. Kumar, A., & Sharma, A. (2019). Ontology Driven Social Big Data Analytics for Fog enabled Sentic-Social Governance. *Scalable Computing: Practice and Experience*, *20*(2), 223-236.
36. Kumar, A., & Sharma, A. (2017). Systematic literature review on opinion mining of big data for government intelligence. *Webology*, *14*(2), 6-47.
37. Jazdi, Nasser. "Cyber physical systems in the context of Industry 4.0." *2014 IEEE international conference on automation, quality and testing, robotics*. IEEE, 2014.
38. Sadeghi, Ahmad-Reza, Christian Wachsmann, and Michael Waidner. "Security and privacy challenges in industrial internet of things." *2015 52nd ACM/EDAC/IEEE Design Automation Conference (DAC)*. IEEE, 2015.
39. Jeschke, Sabina, et al. "Industrial internet of things and cyber manufacturing systems." *Industrial Internet of Things*. Springer, Cham, 2017. 3-19.
40. Wortmann, Felix, and Kristina Flüchter. "Internet of things." *Business & Information Systems Engineering* 57.3 (2015): 221-224.
41. Pisching, Marcos A., et al. "Service composition in the cloud-based manufacturing focused on the industry 4.0." *Doctoral Conference on Computing, Electrical and Industrial Systems*. Springer, Cham, 2015.
42. Singh, S. P., Nayyar, A., Kaur, H., & Singla, A. (2019). Dynamic Task Scheduling using Balanced VM Allocation Policy for Fog Computing Platforms. *Scalable Computing: Practice and Experience*, *20*(2), 433-456.
43. Kaur, A., Gupta, P., Singh, M., & Nayyar, A. (2019). Data Placement in Era of Cloud Computing: a Survey, Taxonomy and Open Research Issues. *Scalable Computing: Practice and Experience*, *20* (2), 377-398.
44. Singh, P., Gupta, P., Jyoti, K., & Nayyar, A. (2019). Research on Auto-Scaling of Web Applications in Cloud: Survey, Trends and Future Directions. *Scalable Computing: Practice and Experience*, *20*(2), 399-432.
45. Singh, S. P., Nayyar, A., Kumar, R., & Sharma, A. (2019). Fog computing: from architecture to edge computing and big data processing. *The Journal of Supercomputing*, *75*(4), 2070-2105.
46. Pramanik, P. K. D., Pareek, G., & Nayyar, A. (2019). Security and Privacy in Remote Healthcare: Issues, Solutions, and Standards. In *Telemedicine Technologies* (pp. 201-225). Academic Press.
47. Pramanik, P. K. D., Nayyar, A., & Pareek, G. (2019). WBAN: Driving e-healthcare Beyond Telemedicine to Remote Health Monitoring: Architecture and Protocols. In *Telemedicine Technologies* (pp. 89-119). Academic Press.
48. Nayyar, A. (2011). INTEROPERABILITY OF CLOUD COMPUTING WITH WEB SERVICES. *International Journal of ElectroComputational World & Knowledge Interface*, *1*(1).
49. Nayyar, A. (2011). Private Virtual Infrastructure (PVI) Model for Cloud Computing. *International Journal of Software Engineering Research and Practices*, *1*(1), 10-14.
50. Bakshi, K. (2016, March). Big data analytics approach for network core and edge applications. In *2016 IEEE Aerospace Conference* (pp. 1-10). IEEE.
51. Retrieved from the https://en.wikipedia.org/wiki/Prescriptive_analytics
52. Mohammadi, M., Al-Fuqaha, A., Sorour, S., & Guizani, M. (2018). Deep learning for IoT big data and streaming analytics: A survey. *IEEE Communications Surveys & Tutorials*, *20*(4), 2923-2960.
53. Berkowitz, B. T., Simhadri, S., Christofferson, P. A., & Mein, G. (2002). *U.S. Patent No. 6,457,021*. Washington, DC: U.S. Patent and Trademark Office.

54. Pokorny, J. (2013). NoSQL databases: a step to database scalability in web environment. *International Journal of Web Information Systems*, *9*(1), 69-82.
55. Karafiloski, E., & Mishev, A. (2017, July). Blockchain solutions for big data challenges: A literature review. In *IEEE EUROCON 2017-17th International Conference on Smart Technologies* (pp. 763-768). IEEE.

Abhilasha Sharma is currently working as an Assistant Professor in Department of Computer Science and Engineering at Delhi Technological University, Delhi, India. She has 11 years of work experience in industry, research and academics. She has received her M.Tech. (Master of Technology) and B.Tech. (Bachelor of Technology) degrees in Information Technology. She is pursuing her Ph.D. in Information Technology from Delhi Technological University, Delhi, India. She has many publications to her credit in various journals and international conferences. Her research area includes Web Applications, Web Engineering, Opinion Mining, Social Web, Big Data Analytics, Social Web based Predictive Modeling.

Harsh Pandey is presently working as software development engineer in Urbanclap. He has received his B.Tech. (Bachelor of Technology) in Electronics and Communication from Netaji Subhas Institute of Technology, Delhi. His area of research includes Machine Learning, Deep Learning, Web Quality Assessment, Sentiment Analysis, Social Big Data, Sustainable Development.

Ubiquitous Manufacturing in the Age of Industry 4.0: A State-of-the-Art Primer

Pijush Kanti Dutta Pramanik, Bulbul Mukherjee, Saurabh Pal, Bijoy Kumar Upadhyaya, and Shubhendu Dutta

Abstract

The industrial revolution has changed the socio-economic civilisation of mankind. It started dating back in the late 1700s and has been in continuous evolution since then. Presently, we are experiencing the latest industrial revolution, known as Industry 4.0. Among others, ubiquitous technologies probably have been the most influential in the implementation of Industry 4.0. This has led to a new manufacturing paradigm known as ubiquitous manufacturing. This chapter presents an in-depth discussion on different aspects of ubiquitous manufacturing. In addition to the history of industrial revolutions and the fundamentals of ubiquitous manufacturing, the topics such as production planning and scheduling, automated material handling system, and dynamic manufacturing are meticulously discussed from the perspective of the real-life scenarios, in the age of ubiquitous manufacturing. The ubiquitous technologies that have enabled ubiquitous manufacturing are reviewed in detail. Several other related and advanced manufacturing technologies such as cloud manufacturing, cloud robotics, global manufacturing, lean manufacturing, agile manufacturing, additive manufacturing, chaordic manufacturing, etc. are duly accentuated. A futuristic view on Industry 5.0 is also presented.

Keywords

Industrial revolution · Lean manufacturing · Cloud robotics · Cloud manufacturing · Industry 4.0 · Industry 5.0 · Ubiquitous technology · Ubiquitous computing · Production planning · Real-time manufacturing · AMHSR · Cloud manufacturing · Edge computing · IIoT

P. K. D. Pramanik (✉)
National Institute of Technology, Durgapur, India

B. Mukherjee · S. Pal
Bengal Institute of Technology, Kolkata, India

B. K. Upadhyaya
Tripura Institute of Technology, Agartala, India

S. Dutta
Aujas Networks, New Delhi, India

1 Introduction

The most impactful revolution in the history of mankind is undoubtedly the Industrial Revolution, and the most intriguing part of this revolution is that probably it is the only revolution without any violence and bloodshed. Unlike other revolutions, it was not a sudden uprising; rather it was a long and slow process, the beginning of which cannot precisely be pointed out and which has been an ongoing process till now. Probably the only revolution that is comparable to this is the Agrarian Revolution, which is the predecessor of the industrial revolution. The agrarian revolution witnessed innovations such as the idea of cultivating crops in rotation on the same field by Viscount Townshend (1674–1738) and a drill, that used to deposit the seeds in straight furrows with adequate space in between, by Jethro Tull (1674–1741). In fact, the industrial revolution is the effect of agricultural societies becoming more industrialized and urban.

The Encyclopaedia Britannica defines industrial revolution as:

> The process of change from an agrarian and handicraft economy to one dominated by industry and machine manufacturing.[1]

For centuries, foods and other necessary commodities such as clothing and houses, and weaponry also were manufactured manually, i.e. either by hand or utilising animal labour [1]. In pre-industrial times, people came up with innovative ways to minimise the manual work; for example, the feedback systems into water clocks, designed by the ancient Greeks and Romans, for self-regulating the devices and the water-driven trip hammers, invented by the Chinese,

[1] https://www.britannica.com/event/Industrial-Revolution

A. Nayyar, A. Kumar (eds.), *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-14544-6_5

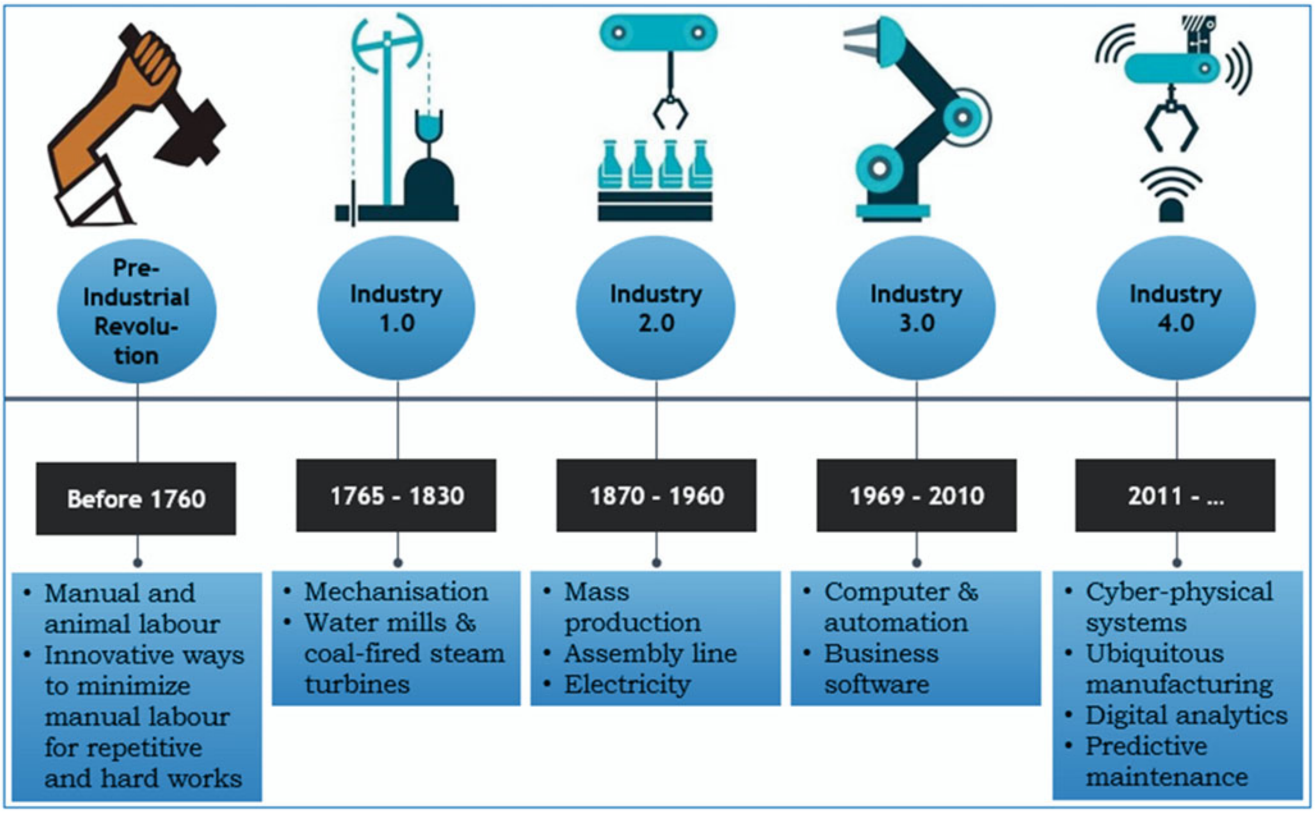


Fig. 1 The evolution of the industrial revolution

to automate the pounding and processing of grains and metals.

Towards the dusk of the eighteenth century and at the dawn of the nineteenth century, with the introduction of systematic manufacturing processes, manufacturing began to change dramatically [2]. That was the beginning of the first stage of the industrial revolution as Industry 1.0; and since then, it is a rapid and continuous uphill climb leading up to the modern industrial era—Industry 4.0. Figure 1 presents an infographic on the different eras during the evolution of the industrial revolution.

Though the idea of a "revolution" in the context of the industry was used since the 1820s by several French and British intellectuals in their articles, the term "Industrial Revolution" was formally coined by Auguste Blanqui, a French economist, in 1837. He used this term to denote the economic and social changes, in Britain, caused by the transition from small-scale home-based industries to the factory-based industries with power-driven machinery [3]. But the term got popularised in 1882 by the great historian Arnold Toynbee. Actually, these "revolutions" are the result of the ground-breaking technical evolutions as well as the reinvention of the existing industry means and resources. These qualitative advancements have sometimes been particularly associated with a certain time period and have had such a prodigious impact that they have been hailed as "revolutions" [1].

For instance, the beginning of the Second Industrial Revolution was marked by the introduction of assembly line production which was first implemented in the industry by the American industrialist Henry Ford (1863–1947) to manufacture his Model T automobiles in 1913. Henry Ford got this idea from the meat-packing lines when he was visiting a slaughterhouse in Chicago. He wrote in his autobiography, *My Life and Work* [4]:

> The idea [of the assembly line] came in a general way from the overhead trolley that the Chicago packers use in dressing beef.

He observed that the animals hung from conveyor belts pass from butcher to butcher and each butcher performed only a part of the task of butchering the animal [5]. The implementation of this principle in automobile production and drastically lowered the cost and significantly increased the production speed. The total floor time for a single car dropped from 12.5 labour-hours to 93 labour-minutes. And a "revolution" began.

The latest revolution the industry is experiencing is the Industry 4.0 (fourth industrial revolution), and the core of which is the cyber-physical systems (CPSs) and the ubiquitous computing and connectivity. Ubiquitous computing is

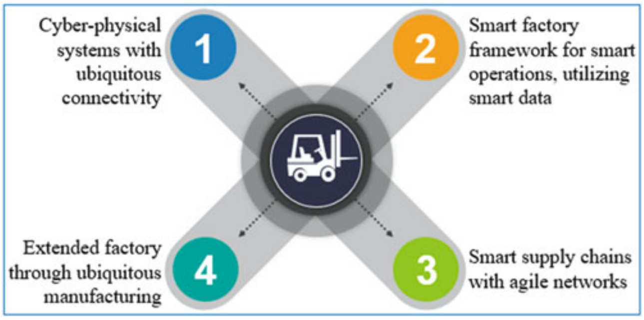


Fig. 2 Dimensions of Industry 4.0

considered the most crucial technological base for the Industry 4.0 implementation [6]. It has paved the way for ubiquitous manufacturing, one of the most important dimensions of Industry 4.0 (as shown in Fig. 2). In this chapter, we explore and understand the details of ubiquitous manufacturing.

The rest of the chapter is organised as follows. Section 2 recapitulates the different stages of the industrial revolution. Section 3 establishes the importance of ubiquitous computing and ubiquitous manufacturing in Industry 4.0. The basics of ubiquitous manufacturing are discussed in this section. In Sect. 4, different components of ubiquitous manufacturing are explained in a practical sense. Section 5 covers the key enabling technologies for ubiquitous manufacturing in details. Several other technologies similar to ubiquitous manufacturing are discussed in Sect. 6. Section 7 dives into the future of Industry 4.0. It discusses the probable features of Industry 5.0 that are supposed to take the manufacturing process to a new level. The chapter is concluded in Sect. 8.

2 The Journey form Industry 1.0 to Industry 4.0

As shown in Fig. 1, in this section, we shall have a brief look at the continuous evolution of the industrial advancements from Industry 1.0 to Industry 4.0.

2.1 Industry 1.0 (First Industrial Revolution)

Following a slow period of proto-industrialization, the first industrial revolution started in the United Kingdom around 1760–1780s and spanned until around 1830s [7]. Industry 1.0 was mainly driven by the mechanisation powered by steam engines which replaced the agriculture and farming with industry to a great extent. The water mills and coal-fired steam turbines allowed to design new kinds of mechanizations, which made the production of goods faster and cheaper with increased quantity and improved quality [8]. The invention of steam-powered locomotive and development of railroads accelerated the economic, human, and material exchanges [7].

The radical change in production ushered in a new economic age and changed the existing social structure. It can be said that Industry 1.0 set the foundation of the industry culture, which focused evenly on quality, efficiency, and scale of production [2].

The highlights of Industry 1.0 are mentioned in Fig. 3.

2.2 Industry 2.0 (Second Industrial Revolution)

The second industrial revolution (also known as technological revolution) took place, mainly in Britain, Germany, and America, in around 1870, nearly after a century of the beginning of the Industry 1.0 era, though the background was set up during 1840–1870. The major thrust behind Industry 2.0 was the emergence of new sources of energy like electricity, gas, and oil, which initiated new technological advancements [7]. The electric-powered machines being more efficient and easier to operate and maintain, more sophisticated machines were developed, which ultimately increased the production greatly.

The introduction of the assembly line streamlined the process of mass production, allowing to produce more product in less time and with lower cost. Since the first electric-powered assembly line built in 1870, various innovative and efficient assembly lines were developed that automated production flows [8].

Another highpoint of this era is that the industry culture introduced in Industry 1.0 was transformed into a management program to make the manufacturing facilities more efficient. Various production management techniques such as division of labour, just-in-time (JIT) manufacturing, and lean manufacturing principles were introduced that refined the underlying production processes, leading to expanded output with improved product quality [2].

The highlights of Industry 2.0 are mentioned in Fig. 4.

2.3 Industry 3.0 (Third Industrial Revolution)

The arrival of the first programmable logic controller (PLC), Modicon 084, in the late 1960s, set the third industrial revolution. Industry 3.0 is driven by the rise of electronics—the transistors and microprocessors, and the computers and information technology. These technological advancements enabled production automation in a wider spectrum.

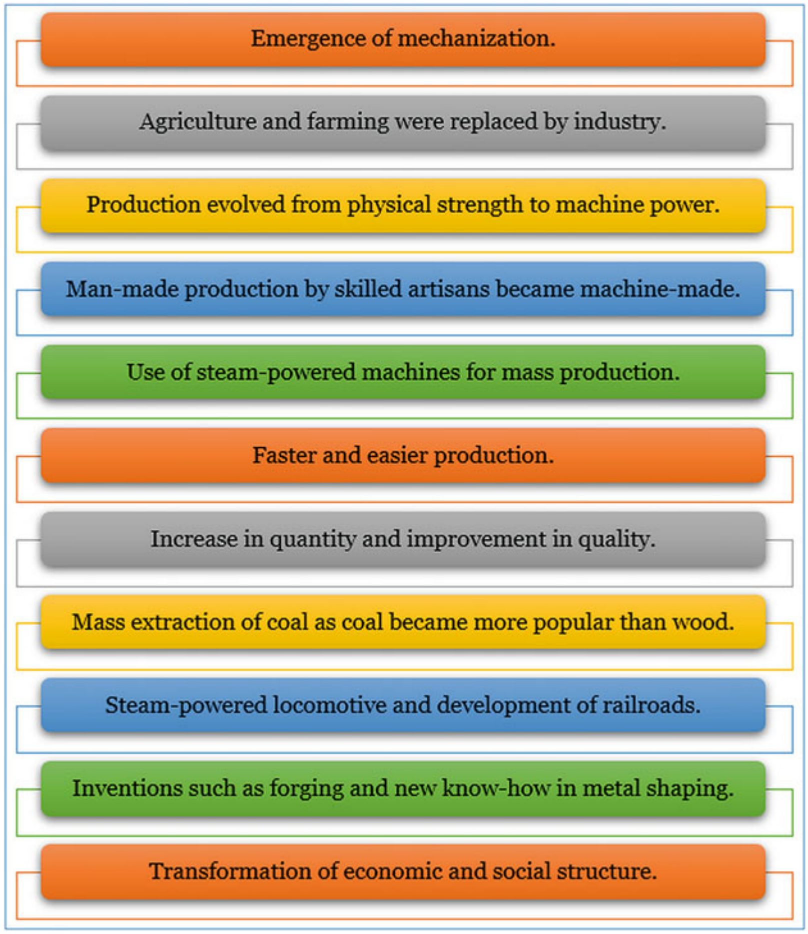


Fig. 3 Highlights of Industry 1.0

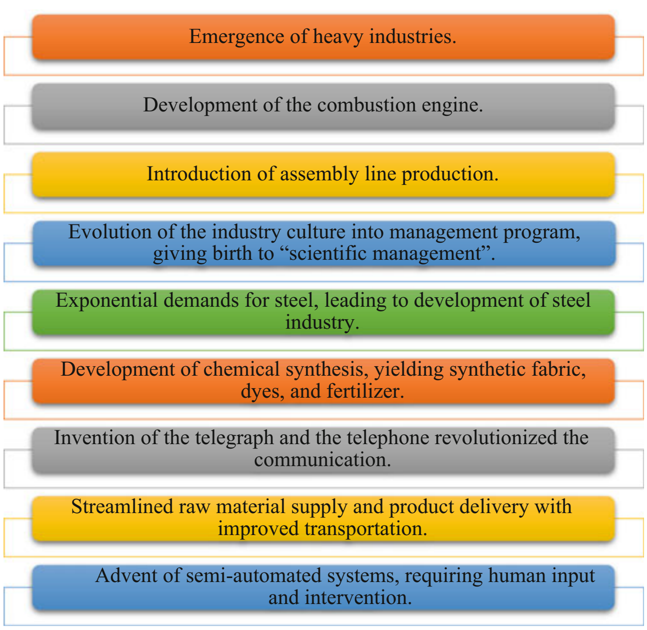


Fig. 4 Highlights of Industry 2.0

Though the term "automation", was coined in 1947 during Industry 2.0 by Delmar Harder, Ford's vice president of manufacturing, to describe the automatic handling of different manufacturing processes by machinery [8], the modern factory automation has fully shaped after the emergence of computers and robotics. The primary goal of automation in Industry 2.0 was to lighten the burden for workers, whereas Industry 3.0 has redefined automation with the goal of flexible mass production on an increasingly large scale. The earlier automated systems required human input and intervention, but the PLC allowed to have independent advanced automated systems in the era of Industry 3.0. Computerised automation, in many cases, even replaced the human factor completely. Factory automation increasingly became a C-suite discipline by the late 1980s, and its mass adoption resulted in reduced effort, augmented speed, and greater accuracy.

But the automation was not limited to only production processes; the advancement in software, along with hardware, allowed to come up with many management processes such as enterprise resource planning (ERP), consumer

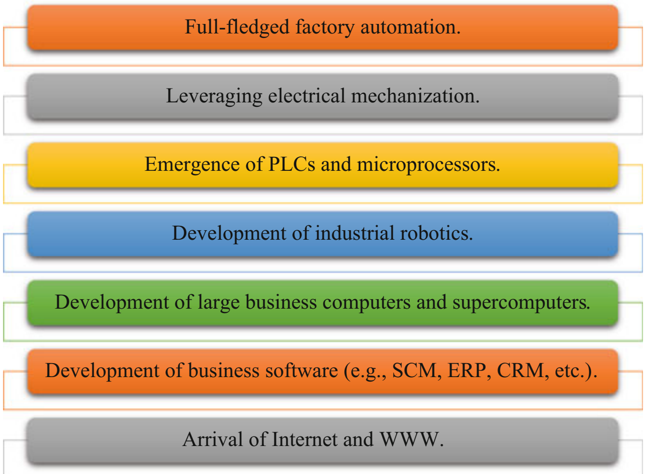


Fig. 5 Highlights of Industry 3.0

relationship management (CRM), material requirements planning (MRP), inventory management, operation management, supply chain management (SCM), product flow scheduling, tracking throughout the factory, etc., which made the overall production activities more efficient [2]. And the development of the hardware and software was well complemented by the revolution in communication systems with the onset of the Internet and related computer communication technologies which allowed the global business to overcome the effort needed for geographic dispersion.

The highlights of Industry 3.0 are mentioned in Fig. 5.

2.4 Industry 4.0 (Fourth Industrial Revolution)

The fourth industrial revolution was first mentioned by Bosch, the German multinational engineering and electronics company, at the Hannover Trade Fair in 2011 to describe the applications of modern information and technological innovations in production [9]. Inspired by the discussions, the German Government took the idea to launch an official project, by the name of *Industrie 4.0*, to prepare the German industry for the future of production.

The emergence of the Internet of Things (IoT), along with other allied technologies such as cloud computing, Big Data, machine learning (ML), ubiquitous computing, etc., has brought this latest revolution in the industrial sector as Industry 4.0. The ubiquitous connectivity, resulted from the intense development in digital communication systems, has removed the boundaries of the physical and the virtual world. It has certainly benefitted the manufacturing industry extensively by augmenting the traditional production operations with certain technological disruptions.

The automation has reached to another level by connecting all production processes and manufacturing techniques through IoT. The factories have become smart with more autonomous machines and processes which can exchange information, trigger actions and control each other independently [10]. IoT enabled the factories to manage themselves virtually [9].

Industry 4.0, applies the principles of CPS, Internet, and future-oriented technologies and smart systems with enhanced human-machine interaction (HMI) paradigms. The essential core of Industry 4.0 is the CPS, which suggests that the physical systems (e.g., machines and robots) are controlled by automation systems equipped with AI, requiring no or minimal human input and operations. Industry 4.0 makes a factory smart by applying advanced information and communication systems and future-oriented technologies [11]. The CPSs and IoT connected manufacturing processes have enabled to share and analyse information globally and in real-time, which helps in taking intelligent actions for various processes in the industry to make the manufacturing process smarter and more efficient. Moreover, the sensor-attached smart machines enable continuous monitoring for detecting and predicting faults which can be used to take preventive measures and remedial action. This allows better preparedness and lower downtime for industries [2]. Not only the production process, but the advantages of CPS, IoT, and ubiquitous connectivity are also harnessed in other aspects in the industry such as logistics, production scheduling, optimization of throughput times, quality control, capacity utilization and efficiency-boosting [2].

The concept of business software was conceived during Industry 3.0 such as manufacturing execution systems, shop floor control and product lifecycle management, etc., implemented with their fullest potential in Industry 4.0, thanks to its cutting-edge technological cooperation such as additive manufacturing, robotics, artificial intelligence (AI), and other cognitive technologies, advanced materials, augmented reality, etc. [1]. Another important feature of Industry 4.0 is the sustainable manufacturing. The emergence of green and sustainable technologies and computing models have been a great boost for this [12–14].

The highlights of Industry 4.0 are mentioned in Fig. 6.

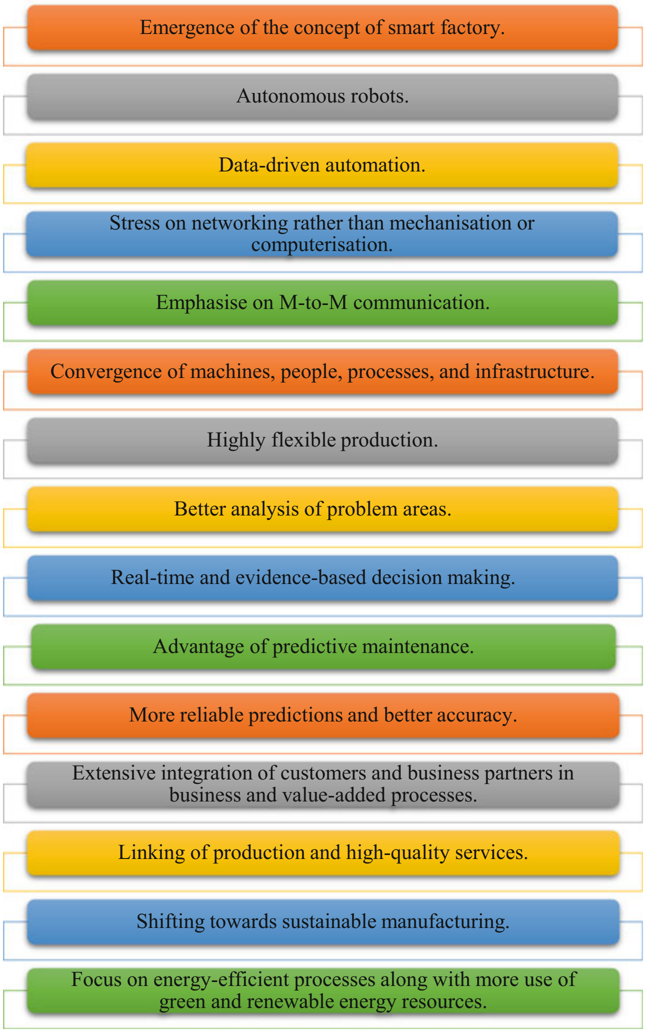


Fig. 6 Highlights of Industry 4.0

3 Industry 4.0 and Ubiquitous Computing and Ubiquitous Manufacturing

3.1 Key Elements of Industry 4.0

Several key factors are responsible for realising Industry 4.0, as shown in Fig. 7. They are briefly discussed in the following.

- **RFID, sensors, and actuators**: Sensors are one of the key elements of Industry 4.0. Sensors bring sense to dumb mechanical devices. The functioning state of a machine could be sensed, monitored and assessed by the sensor in a very efficient manner. Sensor senses and produces data on how a machine is working and other contextual information. There are varieties of sensors which are used in the production industry to measure different physical measures.

  Radio-frequency identification (RFID) is one sensor technology which has been highly used for identification and localization of objects in industry. The RFID technology allows embedding tiny data as hardwired fabrication in the form of tags. The tags are sensitive to electromagnetic radio wave and allow identifying itself by the data embedded within it. The advantages of RFID tags are usage flexibility, very small size (thin), tags are reusable, tags could be read by an RFID reader when comes in proximity without physically contacting or visualizing it [15]. More on RFID can be found in Sect. 5.2.

  Actuators are the mechanical or electromechanical component of a machine or a system which allows moving and controlling mechanism in the system. The actuator converts electric, air or fluidic energy to the movement. The movements are small and could be of two types linear or rotational [16]. Actuators are tremendously used in the manufacturing industry for operating heavy machines, which otherwise is very hard, time-consuming and painstaking to do manually. It allows for very precise movement and controlling of a machine parts or a system.
- **IoT**: Internet of Things is a computing concept which extends Internet connectivity to everyday object; thereby, the devices can communicate with each other by exchanging data. In Industry 4.0, IoT helps to connect different physical entities (mechanical devices) to make a giant network which communicates data among devices and intelligent services for fast and on-demand business decisions [17–19]. IoT has been discussed more elaborately in Sect. 5.3.
- **Cyber-physical system**: Mechanical systems (devices) have evolved and are becoming automatic with the advancements of computing technology. In CPS, mechanical systems (machines) are being controlled, coordinated and monitored by computer and computer-based algorithm. Both the systems are tightly integrated with each other through the Internet and to its users. The computer gives instruction to the mechanical devices for job processing, and the processing feedback is sent back to the computer for assessment. Based on the feedback, computers calibrate the algorithm to obtain optimum job efficiency. CPS not only enhances the job processing efficiency but also brings a sense of automation. More on CPS can be found in Sect. 5.4.
- **Cloud computing**: Cloud computing is an on-demand delivery of computing service over the internet [20, 21]. Services like servers, storage, databases, networking, software, analytics, intelligence and others can be availed as an on-demand basis. It is infrastructural support for services (hardware, platform, and software) over the internet established by public or private parties. The benefits like cost, speed, scalability, performance and

Fig. 7 Key elements of Industry 4.0

productivity are very advantageous to the manufacturing industry in keeping up the pace with changing computing demands [22, 23]. More on cloud computing can be found in Sect. 5.6.

- **Edge/Fog computing**: Enterprise computing for manufacturing often requires real-time computing, and the business cannot depend upon a cloud-centric computing approach. Fog computing paradigm offloads most computing overhead from the cloud and brings it near to ubiquitous or IoT devices, thus reducing the latency [20, 24]. Fog computing advocates devices like routers, switches, Wi-Fi access points, set-top-boxes, base stations etc. in near proximity to the sensor or devices for data computing [25, 26]. By providing service near the edge, fog computing enables better data processing and effective output. More on edge and fog computing can be found in Sect. 5.7.
- **Pervasive and ubiquitous computing**: It is a distributed computing system, which allows spread of computing and sensor devices in the real physical environment with the goal to make each computing and non-computing device to be smart and interactive. The widespread of ubiquitous or pervasive devices allows the user to access the desired information and computing whenever and wherever need basis [27]. Small low-powered computing devices/sensors collect data which are disseminated for processing through the ubiquitous network. The ubiquitous computing senses the context of the user and environment and on the basis of which desired computation is carried to provide necessary information or activity. The objective of pervasive and ubiquitous computing is to make the real-life object interactive among each other and users.
- **Highspeed wireless networks**: Wireless network allows two or more devices (computing devices) to connect each other for wireless data exchange. Wireless networks are quite evident in connecting the different IoT and ubiquitous devices to keep the network connectivity simple, cost-effective and maintenance free. Manufacturing industries are densely crowded with machines, where connecting each and every device (sensors and computing device) over a wired network is a non-trivial task. The problem escalates when the wired network fails, or new devices need to be connected to the existing network. A wireless network allows any number of devices to connect easily at any place without the overhead of physical network establishment and maintenance. But wireless networks are comparatively slow to the wired network, which causes a problem (packet drop) in data communication when a sensor or other ubiquitous/IoT device produces huge data at a high rate. A highspeed wireless network would address the issue much easier. For establishing Industry 4.0 standards in the industry, highspeed wireless network is an absolute requirement. Wireless communications are discussed more elaboratively in Sect. 5.8.

- **Big Data analytics**: Big Data analytics is a complex data processing and analysis procedure which gives a meaningful insight or information hidden in large data set [28]. Big Data analytics is very helpful in getting business and informational insights [29–31].
- **AI and ML**: AI and ML, both not only gather data but also analyses it, thereby transforming the data into information and insight, which helps to make precise business or operational strategies. ML is an application of AI which focuses machines on learning artificially, thereby making intelligent decisions. The algorithms of ML enable the machine to learn and uncover the deep information or insights embedded into the data sets [32].
- **Cognitive computing**: Cognitive computing is a technological platform which employs AI in computing and thus turning it more intelligent and smarter [33]. Cognitive computing simulates human cognition for solving complex problems, particularly the problems which are ambiguous and uncertain. One of the characteristic features of cognitive computing is learning. The computing model learns from experiences and evolves its decision-making capabilities [34].
- **Augmented reality**: It is an interactive and virtual experience of real-world environment or objects where computers augment or superimpose perceptual information over real-life objects. Images, graphics, audio, video and animation, are added to real-world object as superimposed layers of information, further virtual touch and feedback are taken into account for interaction, which gives an enhanced user experience. Thus, augmented reality improves one perception of real-life object [35].
- **Additive manufacturing**: Additive manufacturing is often said as 3D printing. It refers to building components by depositing material layer upon layer. This transformative industrial approach allows building object which are much stronger and lighter. This technology helps to build a great range of shapes, complex shapes without the need for welding or assembling individual parts [36–38]. More on additive manufacturing can be found in Sect. 6.9.

3.2 Ubiquitous Computing

The term and concept “Ubiquitous Computing” was first brought by Mark Weiser at Xerox Corporation in 1993. A computing paradigm which proposes blending computation into the physical environment, so that information could be available anywhere and anytime based on contextual requirements. Mark Weiser stated ubiquitous computing as [39]:

> The non-intrusive availability of computer throughout the physical environment, virtually, if not effectively, invisible to the user.

It is the third-generation modern computing paradigm which characterizes the fact that decisive information would be available everywhere as every day-to-day object has become smart and as they interact seamlessly with each other. In contrast to early generation computing, where one computer serves many users, ubiquitous computing allows multiple computing facilities to serve a single user. The decreasing size of processing technology has been the turning point of realizing ubiquitous computing. Scaling down of digital circuits into mili- to micro-scale encourages processing and sensing technology to embed with everyday devices, making them communicative, sensible and smart. Ubiquitous computing technology is woven into the fabric of daily chores, whereby it enables, mediate, support, and organize our daily activities.

Ubiquitous computing, unlike desktop-based computing, can occur in any smart device, at any place and time, across any network using any data exchange protocol. Thus, ubiquitous technology besides the desktop computers involves a wide range of devices like laptops, notebook, tablets, smartphones, wearable devices, fleet management and control system, control systems, lighting systems, daily appliances, sensors, network devices and any other digital equipment. One of the enabling technologies for ubiquitous computing is sensors. Sensors like RFID, global positioning system (GPS), motion detector, camera, microphone, etc. operate in a standalone manner or embedded with other devices sensing the surrounding environment [40]. Smart devices seamlessly communicate among each other using wireless technology like Wi-Fi, Bluetooth, etc. Analysing the sensed data, and consequently predicting futuristic approach and making decision involves a variety of software with capabilities like AI, data analysis and processing, ML, distributed computing, etc. [40]. Inputs in ubiquitous computing have different modalities like implicit input from sensors where a sensor automatically senses the user’s state, gesture or activities, and environment or by explicit mode where a user inputs voice, hand gesture, text typing or option selection. The data sensed or inputs given are processed on the device or in a distributed manner among devices.

Services like cloud are also popularly integrated with ubiquitous computing for analysing and processing data. The integration of cloud and ubiquitous computing provides very powerful resources (hardware, software, and platform) and services to less enabled ubiquitous technical artefacts. Due to the heterogeneity of devices and output resource constraint (lacking in proper visual display units, printers), the processed result or output is given in the different form (e.g., audio-video, image, text), having different structure and dimensions. In other cases, the output is an instruction to another device for performing a job.

In comparisons to another computer paradigm, ubiquitous computing has the following important characteristics which make it very special in automatically blending computing to a real-life situation [41–43]:

- **Pervasiveness**: Computation capabilities are available throughout our physical environment.
- **Invisible computers**: Computation has been done on any physical entity in any environment, but users are transparent to the computing entity.
- **Task dynamism**: Ubiquitous computing is available everywhere. It provides seamless services to the user by adapting the dynamism of a user, environment and constraints. Further, it adapts to dynamically changing goal and action of the user.
- **Device heterogeneity and resource constraint**: The uniform presence of ubiquitous application could be made either through ubiquitous device carrying the ubiquitous application to move along the user or by widespread of ubiquitous devices all along with the environment whereby the application keep switching among the devices as per the user requirement and movement. Both the approaches adaptability towards the various heterogeneous devices around the user. The devices which a user may carry or use may include computers, laptops, PDAs, notebook, feature phones, smartphones, smartwatches, and display screens found in transportation or other devices. Each device is very different and has many constraints in terms of visual display, sound, processing capacity, memory, and network and data communication. A ubiquitous application which follows the user and moves seamlessly across devices around user adapts to the heterogeneity and resource constraint of devices.
- **Expand human consciousness**: Daily-use physical things are embedded with computation features that expand users' consciousness.
- **Context awareness**: Context awareness is one key characteristic of ubiquitous computing. Context is the situational information about an entity. It describes the state of the entity and its surroundings. Context awareness allows the application to understand the user and its surroundings in a much better way and thus adapting the application operation as per the user situational requirement giving him the best user experience. User context is sensed by the application of the sensor, thereby requirement and state are being inferred by an appropriate model.

Some of the applications of ubiquitous computing are home automation, smart traffic light, learning, health, accessibility, games, logistics, commerce, industries, etc. [44].

In the manufacturing industry, the application of ubiquitous computing has shown Industry 4.0 promising new heights. Industry 4.0 is the new revolution and a trend in automation for manufacturing. It fosters the concept of the smart factory, which involves CPS, IoT, cloud computing, and cognitive computing. In this direction, ubiquitous computing applied in manufacturing process promises to help in realizing four design principles of Industry 4.0—interconnected facilities, information transparency, technical assistance and decentralized decision and thereby fosters dynamism, globalization, unlimited production capacity, and permanent manufacturing service availability.

3.3 Ubiquitous Manufacturing

Ubiquitous manufacturing is a manufacturing paradigm which features "design, makes, and sell product anywhere and at any time". This paradigm allows unlimited manufacturing and services like operations, resource management, logistics, and selling products in a ubiquitous manner. In the manufacturing industry, the wide applications of ubiquitous computing and technology have evolved today's ubiquitous manufacturing.

Ubiquitous manufacturing provides an environment enabling on-demand network access to a pooled configurable manufacturing resources, and thus helps the platform of manufacturing everywhere and anywhere. Recently, in industry 4.0, the ubiquitous manufacturing is supported by ubiquitous technologies such as RFID, GPS, automatic identification (auto ID) sensors and autonomous industrial mobile robots as logistics, distant operation and virtual control of robotic arms or computerised numerical control (CNC) machines through wireless sensor networks (WSNs) or through the global system for mobile communications (GSM) networks.

Ubiquitous manufacturing can be considered as wireless manufacturing or e-manufacturing. Wearable devices in factories can detect an operator's exhaustion, support in the training of operators, and promptly aware an operator to the operation error. A real-time WIP management system for a small, flexible manufacturing system (FMS) can be obtained by using smart objects such as RFIDs, auto-IDs, and web services. RFID tags are used to recognise operators, pallets, and locations on the shop floor. RFID readers are united with a smart gateway and enfolded with Web services to be called with no effort. Thus, while the material flows in the FMS, the WIP level could be easily monitored, and, accordingly, appropriate shop floor control actions could be adopted. In logistics, RFID tags are used to identify goods to avoid misplacement, and weight sensors to avoid the overload of vehicles [45]. Thus, heterogeneous information sources are accumulated to assist the decision making.

Manufacturing is a combined, coordinated, and harmonized process of all levels of production from acquiring raw materials, to the processing at machine levels, operations, logistics, end product retailing and to entire business level. The entire production process is a complex procedure and requires synchronization of many subsystems at a different production level. Over the years, manufacturing has evolved tremendously. Due to globalization and dynamic market requirement, the scope of manufacturing has crossed geographical boundaries. The availability of raw material, transportation, and labour issues which cause cost overhead had forced the manufacturer to explore new possibilities like distributed manufacturing and adapting to technologies like robotics, remote manufacturing, computers in manufacturing and internet technology etc. The fast-growing business, market dynamicity and the rising competition has accelerated manufacturer to be more agile, responsive, efficient, customized and productive. The makeover changes in the production industry in meeting the market demands have led to issues like complex manufacturing operation, production process synchronization, production data management, etc.

The objective of permanency, sustainability, agility and quickness in manufacturing in a competitive market has given force to ubiquitous manufacturing. Ubiquitous computing technology comprising of distributed (logically or spatially) computing, sensors, communication technology, web services and IoT which applied to manufacturing, addresses a broad range of manufacturing activities like manufacturing processes (assembly, machine operation, etc.), production scheduling, logistics and inventory, quality control (maintenance and product quality testing), etc. The manufacturing process produces enormous real-time data; ubiquitous computing allows processing these data for a range of services, like decision making, system reconfiguration and agile manufacturing. These information and communication services lead the manufacturer to an error-free production process.

Ubiquitous technology in the manufacturing process and operation lead to ubiquity. The technologies which are broadly used in ubiquitous manufacturing are discussed below [46].

- **Ubiquitous sensor**: Ubiquitous sensors are sensors which are applied in ubiquitous manufacturing. The ubiquitous sensor includes various sensor technologies like RFID, auto ID, Kinect, virtual reality, CPS, GPS, GSM, and Wi-Fi etc. Among the other available sensors, the use of RFID is quite popular in manufacturing for automatic and real-time object tracking. The other sensors, like GPS, GSM, and Wi-Fi, are also used for location and positioning, diagnosis, and control. The use of the sensor for streamlining data production on manufacturing operation gives clear operational visibility, improved responsiveness, automation, and cost reduction.
- **Web services**: In manufacturing, web services are becoming vital technology in design, control, information management, and decision making. Manufacturing design tool available on the Web, allows the manufacturer in production and designing anytime and from anywhere. Besides, it allows the manufacturer and customers to interact in business-to-business and business-to-customer e-commerce model, independent of time and location constraint. The data analytics web services would allow the manufacturer to take decisive business strategies, monitor machine state and status, and predict failure. The prior knowledge of future machine functioning and failures would allow to take preventive measures and often remote diagnosis, thus saving money and time. More on web services can be found in Sect. 5.9.
- **IoT**: As discussed earlier, IoT allows machines (things) at a different level of production to connect through the Internet. The manufacturing machine fitted with sensors captures the states and functional operation of machines. The data thus produced are analysed in the cloud to know the present and future state, and machine functioning. This allows remote control, and automatic diagnosis and preventive measure. Thus, the things by understanding the requirement and operational patterns act intelligently in response as per the environmental and contextual situation. For more on IoT, please refer to Sect. 5.3.
- **Real-time decision making**: Real-time decision making ensures manufactured product are delivered appropriately to the customer. The customer may relocate; thus, the real-time decision making in real-time data based on the GPS location of the customer ensures products are delivered to the right customer at the right place. RFID and GPS are two most effective sensors for collecting real-time data. Besides, the real-time data on production machine operation helps in detecting and diagnosing the current and future errors. The abnormalities found in the data pattern helps in assessing the malfunctioning and take real-time decisions.
- **Social network**: A social network is the relationship network among different production facilities to share resources for approximating competition, increasing profits and reducing costs. It is a virtual capacity network, which allows gathering factories which intend to acquire or take the rent of production facility and factories which intended to sell or rent its production facility or machines. Further, it acts with information service providers for matching the demand and supply of machines and resources.

The use of ubiquitous technology in manufacturing is varied and widely used in all dimensions of industrial business. The application of ubiquitous technology is found from the manufacturing process at the workshop floor to logistics and inventory control. The different avenues where ubiquitous technology is applied are as follows [47]:

- **Manufacturing processes**: Ubiquitous technology is applied in various manufacturing processes. There are four types of the manufacturing process where ubiquitous technology could be applied, namely joining process, subtractive/material removal process, near-net shape and additive manufacturing, supportive process.
- **Manufacturing control system**: Ubiquitous technology or ubiquitous computing technology is used crucially in the manufacturing control system. The control system implemented in a manufacturing facility is often centralized or de-centralized. The control system monitors the working condition of manufacturing machines and any critical events. Subsystems like data acquisition systems, sensor network, actuators and control devices are highly involved in the control system for ubiquitous manufacturing. Recently, the control systems are involved in monitoring energy consumption in a ubiquitous manufacturing environment.
- **Logistics**: Keeping the production performance high, proper utilization of resources and delivery of the product to customer logistics are important. Ubiquitous technology or ubiquitous computing technology in logistics helps in meeting ubiquity in the manufacturing process. Location and movement-based sensors keep track of production flow. This ensures supply-demand balance and scheduling of production meet as per demands. Tracking and control of conveyor movement, trucks or transportation, crane movement, automated guided vehicle (AGV) ensures efficient manufacturing and ensures demands are met at the right time and at the right place.
- **Production scheduling**: Ubiquitous technology or ubiquitous computing is widely used for production scheduling in manufacturing. Production task is allocated to machine based on criteria like the first task first, task priority, minimizing production time span and cost. Production data and its pattern are analysed by data analytics and cloud service to obtain efficient production scheduling. For open real-time scheduling, in ubiquitous manufacturing, RFID and IoT technologies are widely used in manufacturing facilities. Wide ranges of techniques such as Big Data, artificial neural network (ANN), and mathematical models have been used to obtain optimum scheduling. Production scheduling has been further discussed in Sect. 4.1.
- **Production inventory and resource control**: Manufacturing management and process planning in a production facility includes production inventory controls, production resource control and management and manufacturing service compositions. Ubiquitous computing technology such as cloud service is used for production, inventory and manufacturing services as per the need basis. Cloud computing technology and IoT are integrated with the production facility to improve performance [48, 49]. It integrates different granular manufacturing services into a layered structure. The other applications of cloud services are collaborating with distributed manufacturing, essential manufacturing service composition, data integration, and resolving the supply and demand matching problem. Further, the cloud services, like Big Data analysis and data mining techniques, are used for production resource allocation planning.

Industry 4.0 introduces new concepts such as digital threads, digital twin, and CPSs to enable decentralized, self-controlled systems and processes and to ensure improved communication and collaboration from initial product design to end-of-life and recycling [50]. The computational capacity and capability of self-controlling and self-assessment are gained by technologies like cloud computing, Big Data, Blockchain, connectivity with IoT, advanced analytics with ML and AI, HMI with mobile and wearable technologies, augmented and virtual reality, cognitive HMI, and digital to physical conversion with advanced robotics or 3D printing.

3.3.1 Advantages of Ubiquitous Manufacturing

The advantages of ubiquitous manufacturing are overwhelming in the way how industrial automation can be made easy and customized to manufacturer needs. The advantages of ubiquitous manufacturing have propelled the industrial automation revolution "Industry 4.0" to new horizons. Among the many advantages of ubiquitous manufacturing [51–55], the ones which are worth mentioning are as following:

Faster and More Informed Decisions In ubiquitous manufacturing, the adaptability to ubiquity leads to much faster and informed decision making. Ubiquitous devices in manufacturing make available all kinds of machine, operational and logistic data in one click. The data analytics over the industrial data reveals critical data and accurate insights on any situation. This empowers to take a higher quality decision much quicker.

Quality Improvements Quality product leads to lower wastage, higher customer satisfaction and improved sales. Improved quality product implies zero defects or error in the manufacturing process. Faulty manufacturing equipment always reasons for defective or poor-quality products, and most of the time, manufacturers are not aware of the problems with the equipment. Often the defects in the product are not visible at the quality inspection, but are visible much later when the product is sold to a customer. This has far-reaching consequences like customer dissatisfaction, downsizing product and company name etc. Based on the data acquired at each step of production, from the manufacturing process to packaging, the entire production life cycle of a manufactured product is visible in ubiquitous manufacturing. Appropriate data analysis predicts and detects quality defect trends along with their causes. Applying a corrective course of action would lower the wastage and improves the production process.

Enhanced Productivity Ubiquitous manufacturing improves the overall throughput of the factory. In ubiquitous manufacturing the production facilities are connected, whereby the ubiquitous technology provides the manufacturers with seamless visibility for the different bottlenecks in the processes, machinery and operational performance issues etc. The information helps the manufacturer to make the appropriate adjustment to improve quality and production.

Innovation and Higher Quality Products In ubiquitous manufacturing, ubiquity not only interconnects the various manufacturing processes but also links customers directly to the manufacturer. The data analytics shapes the customer's feedback and presents the requirements which are useful to the manufacturer. This gives the manufacturer the opportunity to improve the product line or innovate new products.

Maximum Flexibility One of the critical aspects of manufacturing is meeting the dynamic market demands. The ups and down in the market produce a fluctuation in production. To meet the dynamic production demand, factory logistics must support the floating manufacturing requirements. This is a challenging task in terms of production scheduling, resource distribution and logistics, supply and distribution of finished products. The ubiquitous feature of ubiquitous manufacturing in this direction ensures to meet production flexibility. Advanced sensor technology senses the new production demand and automates the logistics, and supply for production. This allows the manufacturing industry to meet the supply chain demand with greater agility.

Predictive Maintenance In manufacturing, faulty machine maintenance causes production downtime. Scheduled maintenance or maintenance based on historical maintenance data do not often suitably minimizes the downtime. The ubiquitous technology in manufacturing gives better visibility for predicting and resolving the maintenance issues before it can cause production downtime. Ubiquitous sensors, affixed to the machine, provide real-time information on machine condition and its operational efficiency. This gives the maintenance team a pre-hand knowledge on machines which may need maintenance in future. Thus, performing maintenance at off-time could minimize the production downtime which otherwise had caused for repairing a faulty machine.

Reduce Workforce Challenges The applications of ubiquitous technology in manufacturing have led to automation. The machines in the production shop floor are more connected and take an intelligent decision for production. With an increase in automation in manufacturing floor reduces human intervention leading to fewer workers. Workers, instead of focusing on machine handling and operability, could focus on their core responsibility.

Energy Efficiency Energy consumption in manufacturing is huge, which cost a lot to manufacturers. Monitoring energy consumption and the wastage in each production process is vital to save energy. Machines in the production shop floor during off-hours and the other underperforming machines consume huge energy. Use of ubiquitous technology like the sensor is very effective in monitoring the energy consumption of each machine at the granular operational level. The sensors collect energy consumption data for machine right down to each unit operation level, thus giving a real-time insight on energy consumption statistic of machines. This gives the manufacturer clear knowledge of which machines are consuming extra energy and when. Probably, it is a better inference mechanism to identify the underperforming machines. Strategies like machine power automation, optimizing production scheduling, maintenance, machine replacement and others help in saving energy and money.

Cost Reductions Ubiquitous technology leads to connected devices and machines. The data collected helps the manufacturer to visualize the production efficiency, wastages and foresee the issues which may go to rise. Ubiquity leads the manufacturer to have better insight into supply-chain issues, inventory level, delivery status, and production efficiency issues. Optimizing supply-chain issues, inventory control, and manufacturing and maintenance issues drastically reduce wastage, energy consumption, production downtime and these directly translate to cost savings. Some of the avenues where costs can be reduced considerably are energy cost, inventory handling cost, downtime cost, maintenance cost, labour cost, etc.

3.3.2 Challenges of Ubiquitous Manufacturing

Application of ubiquitous technology is new to manufacturing. Lack of standards and architecture raises challenges in its acceptance and implementation in industry. Some of the challenges are as follows [46, 56–58]:

Acceptance Challenge There is a lack of awareness of ubiquitous manufacturing in the industrial community. Manufacturers are unaware of how the ubiquitous technology in manufacturing would benefit to their productions. As a reason, most manufacturers are reluctant to accept ubiquitous manufacturing technology.

Cost and Maintenance Challenge Setting up ubiquitous facility which leads to automation and virtualization of the production facility and their continuous maintenance incurs costs. Ubiquitous devices are delicate and may get damaged or turn erroneous due to industrial heat, moisture, chemical fumes, dust, heavy machinery vibrations, physical impacts, etc. For error-free performance continues testing, and maintenance of these devices which are installed in all possible places is a really a difficult job. Maintenance like software installation, bug fixing, device replacement, error testing and calibration would result in frequent process breaks. This cause business downtime, which makes adopting ubiquitous manufacturing a difficult proposition to accept for manufacturers.

Interoperability Challenge Ubiquity encourages distributed manufacturing, where products/items are manufactured in many small-batch manufacturing facilities. The finished product of one manufacturing unit can be a resource for others. The exchange of products and item between the facilities requires semantic interoperability among them. Establishing automatic interoperability, where machines in production line understand and communicate among each other for production is an arduous task. Semantic interoperability needs knowledge of contextual information of machine and surroundings, ontologies, linked data structure, etc. The semantic interoperability allows for production scheduling, control and maintenance management. Ontologies are discussed in detail in Sect. 5.13.

Machine Reconfiguration Challenge One of the key features of ubiquitous technology is adaptability. As per the contextual requirement, ubiquitous technology keens to adapt to fit in demand. In ubiquitous manufacturing, machines in production could be devised to produce new products. One of the challenges in ubiquitous manufacturing is configuring the heterogeneous manufacturing resources through virtualization so that the manufacturing process could be applied for the production of any new products in a plug-and-play manner.

Abundant Data Data acquisition and transmission is the backbone of ubiquitous manufacturing. In a manufacturing facility, different types of machines work together. The sensors or data collecting interfaces affix to machines produce an enormous amount of data. The data being produced are heterogeneous in nature, having different data type and structure. Integrating these data is a complex endeavour. Further, the transmission and processing of the enormous amount of data considerably network intensive task. For data communication, ubiquitous devices are networked in distributed or centralized fashion using wireless technology like Wi-Fi or Bluetooth. When the machines are working at their fullest capacity, enormous sampling data are produced by sensors. This may put a huge load on the wireless network resulting in packet loss. Often the caching scheme for data store and transmit is not sufficient since the sensors have low memory and data produced are overwhelming than the storage capacity. In another case, where sensor data of one machine is exchanged as a snippet to other machine poses a challenge in data integration and consistency.

Data Analytics Ubiquitous devices in manufacturing produce huge data, which are heterogeneous in structure and type. Analysing these data to find needful information using traditional data processing methods is inefficient. Use of data analytics and Big Data technology over production data is effective for skimming accurate information and getting useful insights. With the acquired intelligence and knowledge manufacturer are benefitted for future product design, decision support, operational support and guidance. But selecting the data analytics and Big Data technology for processing the data has many challenges as:

- Determining the right data that would be useful for a business decision.
- Processing huge volume of a variety of production data produced at high velocity.
- Synchronizing and sharing of appropriate and accurate information between the different business units.
- Putting the analysed result in a presentable format for decision making.
- Determining which data analytics service or Big Data tool would be appropriate for analysing data.

4 Components of Ubiquitous Manufacturing Implementation

As we discussed earlier, the goal of ubiquitous manufacturing is to enhance the efficiency of the processes, shortening the fulfilment time of orders, reducing machine set up time and most importantly adapting to the processes based on the contextual environment through real-time sharing of information among the various manufacturing processes, equipment, products, and systems. Ubiquitous manufacturing is also sometimes referred as “Smart factory” since the new methods of manufacturing infuse a greater level of intelligence in machines and people using new technology components such as smart sensors, in-built processors, connectivity, cloud application, analytics, 3-D printing, Blockchain, etc. The smart factory is defined in [59], as:

> A factory that is context-aware and assists people and machines in the execution of their tasks by systems working in the background, so-called Calm-systems and context-aware applications.

Context-awareness, here, refers to the knowledge of the position and status of objects of interest with respect to its environment, where calm-systems are its hardware and context-aware applications are the software.

The building blocks for the ubiquitous manufacturing are the embedded sensors, microprocessors, software and connectivity in products which is coupled with a product cloud in which product data is stored, and some applications are running. The embedded sensors in the product, identify information from its physical environment (geolocation, temperature, light, humidity, etc.) and communicate in real-time with the smart environment where the relevant manufacturing information is decentralised. This location and state-specific information are instantly shared with the manufacturing system to trigger a production process which substantially improves the inventory turnover and reduces the machine idle time. Furthermore, the huge data that is exchanged across machines and system is stored and analysed in the cloud environment that offers rich insights about the manufacturing environment, the demand pattern and inventory bottlenecks.

With the use of low-cost sensors, powerful microprocessors, ubiquitous connectivity, and AI technologies, the products and machines become smart in the sense that they not only have the capabilities of sensing the changes in its state due to environmental factors, but also communicate with its ecosystem to adjust and adapt to these changes by taking autonomous decisions. This requires the ability to compute, communicate and control, along with a degree of autonomy. This ability to adjust to and learn from data in real-time can make the manufacturing units more responsive, proactive and predictive, enabling the organization to avoid operational downtime and other productivity challenges. It has a huge potential to transform the manufacturing processes that are driven by the traditional method of information flow across the various processes. In the traditional manufacturing process, the input to production planning is received either through confirmed sales orders or sales forecast, which is fed into the system through human intervention. In contrast, the information flow in ubiquitous manufacturing is facilitated through machine to machine interaction, thus capturing the data instantly right from the source, leaving no room for manipulation of this operational data. In the subsequent sections, we discuss how ubiquitous technologies impact the various manufacturing processes.

4.1 Production Planning and Scheduling

Traditionally, production planning and scheduling are executed by following the specific manufacturing strategies depending upon the demand pattern of the finished product. The information about customer demand in terms of firm order or demand forecast is generally captured in the ERP system, which triggers the production planning process following the master production schedule and the material requirements planning route. A schematic view of the production planning system is presented in Fig. 8.

In Fig. 8, it is worth noting that the information is fed into the production planning system from the top (sales order) while the downstream information is processed using the business logic inherent in the ERP system. However, this does not account for the dynamic information of inventory on the shop floor or the state of machines, while generating the production order or the purchase order. This results in the following issues:

- The paper-based information fed into the ERP system always has a latency between the actual shop floor information and the ERP data affecting the information quality and hence the accuracy of decisions with regard to the production process [60].
- For the production scheduling, the lack of real-time warehouse and the work-in-process inventory data leads to wrong scheduling of machines causing long wait time and inventory pile up [60].
- In multistage operations, due to lack of synchronisation between warehouse, shop floor inventory, machines, internal transportation and material handling team, the warehouse is often flooded with inventory causing high inventory carrying cost besides customer order fulfilment issues [61].

We now explore the above issues in detail in the specific manufacturing scenarios and examine the role of ubiquitous manufacturing in addressing these issues.

Most of the manufacturing units follow either a make-to-order strategy of a make-to-stock strategy which are discussed in the following two subsections from the view of ubiquitous manufacturing.

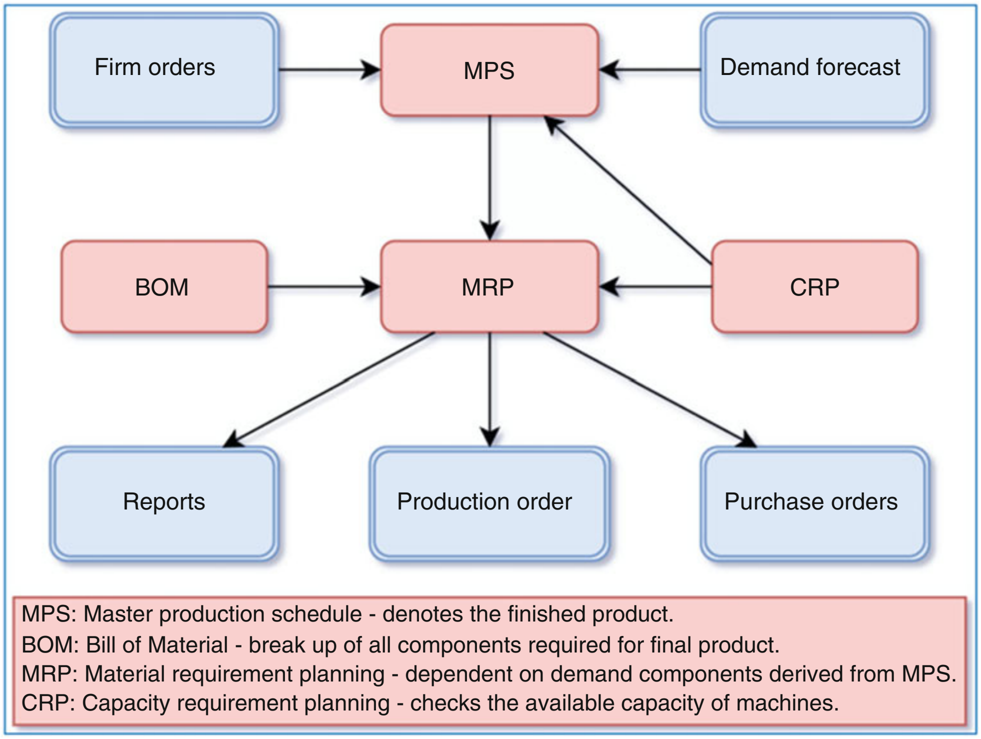


Fig. 8 Traditional production planning workflow in an ERP system

4.1.1 Make-to-Order Strategy

Make-to-order manufacturing strategy is followed when the materials are produced for specific sales orders, and all the costs incurred towards manufacturing are tracked at the sales order level rather than at the material level. In other words, the production process is triggered only when there is firm demand for the product. Therefore, make to order strategy always supports a very close customer-vendor relationship through a seamless flow of information because sales orders are closely linked to production. This manufacturing strategy is also followed in production using variant configuration and assemble-to-order environments (e.g., ship building or aircraft manufacturing). However, the challenge in this production strategy is to keep the replenishment lead time (time to refill the inventory) low while maintaining a minimum work-in-progress inventory. In the traditional process, customer orders are processed manually by planners with an assumption of unlimited resources/capacities of the machines. Planners have inadequate information about job statuses at the manufacturing sites, leading to a very high level of work-in-process (WIP) inventories and long wait time between the machines. Orders are released by a paper-based mechanism, which is time-consuming and tedious. Significant amount of time is spent on waiting for material arrival or completion of preceding operations [61]. In addition, other disturbances like frequent engineering and customer changes, bring a higher number of emergency orders, which cannot be managed by the manual production planning system. This overall leads to a high-cost of manufacturing, customer dissatisfaction due to non-compliance to customer requirements and high production lead time.

In ubiquitous manufacturing, the resources used, i.e. man, machine, and product, are enabled by ubiquitous devices for real-time communication and decision making during the production process. This is enabled by the new age technologies such as sensors, microprocessors, connectivity and software application that has the potential to solve some of the above-mentioned issues in the traditional manufacturing process. First, the customer order can be converted into a prototype using 3-D printing that validates the specification and other details required by the customer to avoid rework at a later stage. 3-D printing or additive manufacturing is a process by which a digital 3-D design data is used to build up a component in layers by depositing material. Generally, the complex structures which cannot be manufactured using traditional tools can be produced using additive manufacturing that substantially reduces the cost of manufacturing. Secondly, the use of sensors in the product in making help locating the status of each subcomponent of the final product. The sensors, enabled with real-time location system (RTLS) technology [27], can inform the state of each subcomponent to the downstream production system and thus can help to schedule the machines properly without any idle time. With all this information stored centrally, the customers can also view the real-time status of their order and can track this easily. The communication between the machines and the product helps in better coordination of the entire production process.

4.1.2 Make-to-Stock Strategy

Make-to-stock manufacturing strategy is applicable when the materials are not assigned to any sales order, i.e. stocks are produced independent of the sales order, and the goods can be provided to the customer from the stock whenever the order needs to be fulfilled immediately. Goods are produced anticipating future demand. In this scenario, the dependent demand components (e.g., components of automotive parts) are produced based on forecast demand and the final assembly is done when the customer order is received. An apt example of make to stock strategy is the production of vehicles, where the individual components are produced or procured as an independent requirement which is assembled using the assembly line process when a sales order or forecast order is received.

The most important challenge in executing this manufacturing strategy is to accurately forecast the demand and offer a mass customised product to the customer. In the traditional manufacturing process, where the demand forecast is made using the heuristics, and the scheduling is done using manual processes that do not take into account the actual status of WIP inventory and the machine loading status, the lack of synchronisation across the entire production process leads to high wait time and inaccurate demand forecast. These inefficiencies can be overcome using the RFID-based communication and integration of the real-time information with a production planning system such as ERP and provide a real-time decision support system for the man and machine on the shop floor.

4.1.3 Real-Time Scheduling

The issue of production scheduling becomes important when the manufacturing takes place across various geographically spread locations, and the customer order requires multiple processes, some in parallel and some in series. For example, in the case of dependent demand products, the components can be manufactured or sourced from various locations using multiple manufacturing processes involving lathe machines, furnaces, foundry, painting, etc. The production process sometimes becomes very complex when the customer order has more than 20 products with various colours and each requiring different workflows in different manufacturing plants while all are required to be shipped together. This requires creating a production schedule by fetching real-time information across all the machines, WIP inventory and warehouse integrated with ERP data. The machine set up time for various processes has to be factored in, while preparing the schedule for such a case.

Real-time scheduling will be equally critical when frequently changing customer requirements demand frequent switching between different types of products with smaller lots. This can be accomplished by the dynamic routing of resources, namely machines and raw material using the real-time sharing of information through highly flexible and reconfigurable manufacturing systems [60]. This agile flexibility allows ubiquitous manufacturing units to adapt to schedule and product changes with minimal intervention. Such units can also self-configure the equipment and material flows depending on the product being built and schedule changes, and then see the impact of those changes in real-time. Additionally, agility can increase factory uptime and yield by minimizing changeovers due to scheduling or product changes and enable flexible scheduling.

4.1.4 Advantages of Using Ubiquitous Manufacturing in Production Planning and Scheduling

Some of the main advantages of using ubiquitous manufacturing in production planning and scheduling are as follows:

- **Synchronised decision making**: There are three sources of data that is generally captured and integrated for synchronised decision making. The first source is the real-time information in the form of RFID from the shop floor, warehouse, machine status and the location of material handling equipment (e.g., forklift). The second source of information is the traditional ERP system that captures the sales order and the MRP data, which is largely static in nature. The third source is the output data from the upstream system, i.e. production scheduling, which is the input for transportation decision and the warehouse inventory. Finally, all this information is fed into the cloud-based algorithm pool that runs an analytical model to generate an optimised solution for the production schedule, transportation route and the warehouse inventory.
- **Improved productivity**: Compared with the traditional production line, the ubiquitous manufacturing can produce small-lot products of different types more efficiently. On one hand, the setup time is minimized when switching between different types of products while on the other hand, as the production process is optimized with the help of decision support system and coordination through real-time data exchange, the average manufacturing routes are shrunk, and the utilization rate of machines and other resources is improved [60].
- **Faster customer order fulfilment**: In cases where a product is manufactured through multiple manufacturing processes (e.g., machining, heat treatment, painting, assembling. etc.), spreading across multiple locations, it is important to have a synchronisation among the various processes and the machines to fulfil a customer order in the shortest possible time [60]. In other words, the objective function is to minimise the total production flow time of all

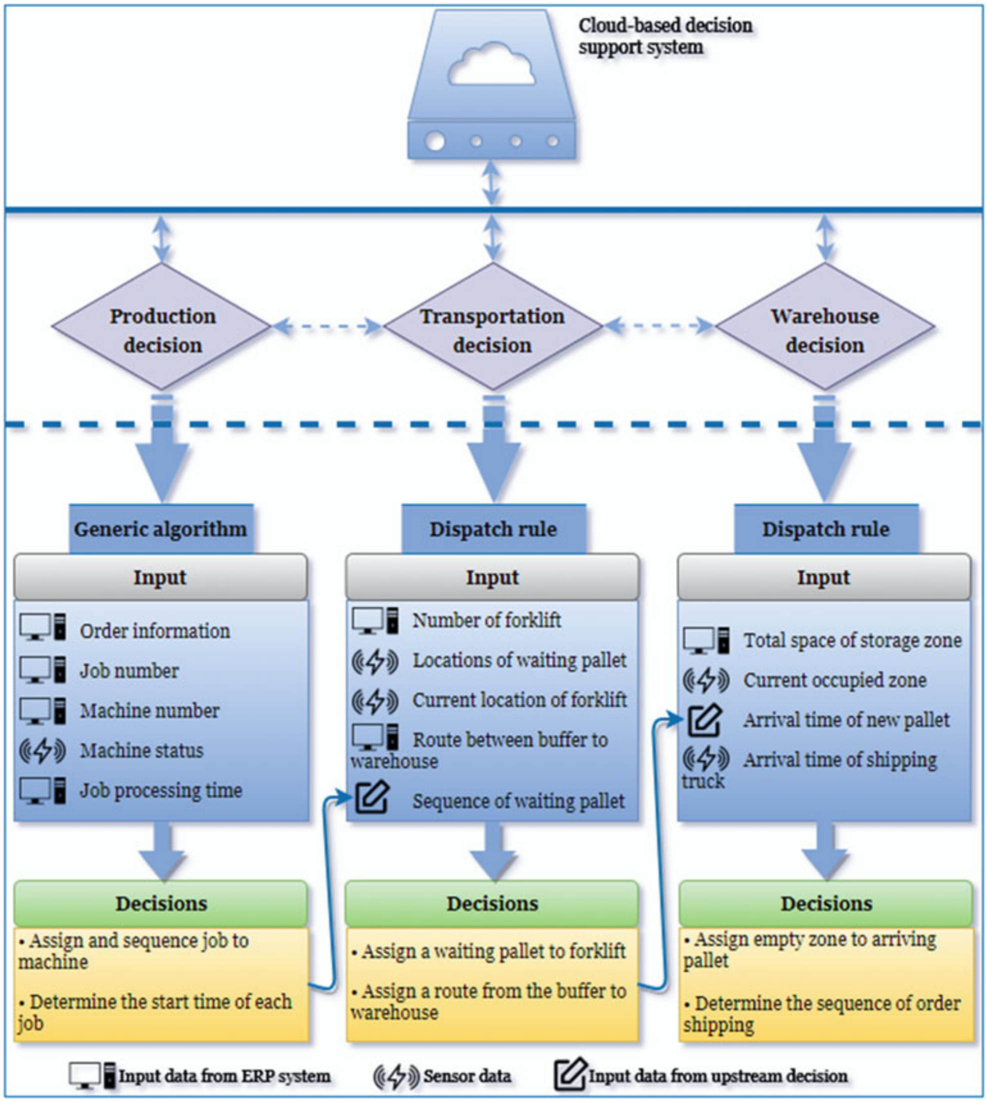


Fig. 9 Real-time information flow across production, transportation, and warehouse (adapted from [61])

orders by minimising the set-up time of the machines. This is possible in ubiquitous manufacturing set up with information about a particular sales order (ERP) integrated through the real-time location information (RFID) of all inventory along with the status information of the machines to generate an optimisation model using the AI.

- **The synchronised decision in transportation schedule**: When a customer order needs to be fulfilled through multiple processes running in different locations, a high degree of synchronisation is required between the customer order, production facilities, the warehouse location of finished product and the transportation equipment. The objective of the transportation scheduling model is to minimise the total transportation flow of all orders, i.e. minimising the duration between the first-moved job to the last-moved job in each order, while keeping the total moving distance of all forklifts to the minimum.

Figure 9 explains how the information flow across sensors and ERP data leads to better synchronisation for decisions across production planning, transportation, and warehouse.

4.2 Automated Material Handling Systems Routing and Scheduling

Automated material handling system (AMHS) is a combination of equipment, software, connectivity and sensors that enables the automated movement of goods in the factory premise, protection against environmental hazards, storage at the designated location and control of material and products' quality throughout manufacturing, warehousing, distribution, consumption and disposal phases. In most of the flexible manufacturing system, AGV (Automated Guided Vehicles) is used for automated material handling purposes that are computer controlled, wheel-based load carriers that travel along the floor of a manufacturing facility without an onboard operator or driver. Their movement is directed by a combination of software and sensor-based guidance systems and a near field connectivity that keeps probing its neighbouring environment to detect any obstacle because they move on a predictable path with precisely controlled acceleration and deceleration and include automatic obstacle detection bumpers, AGVs provide safe movement of loads without any collision with other AGVs or any nearby objects.

Typical AGVs are used in the transportation of raw materials, work-in-process inventory, and finished goods from one point to another of manufacturing production lines, and storage, retrieval or other movements in support of picking in warehousing and distribution applications in much more coordinated fashion to avoid in process delays [62]. The product movement starting from the raw material stage to finished product stage is equipped with an RFID readable tag that contains the production process required at each stage. This information helps the machines organise to carry out the required process and configure the production route while the content of the RFID tag is kept updated during the production process. Synchronisation across the machines and the AGVs using the RFID tags and ERP system helps to minimise the wait-time for the product. While the ERP system has the static information about the production process steps, the RFID embedded AGVs offers the real-time view of the material in process and the state of the machine which is used in dynamically configuring the routing path. Once the processing is complete, and the product is ready to be dispatched, the information is shared with the warehouse system to create storage space.

In order to ensure a conflict-free routing and dispatch of material, the path to be followed by the AGVs is dynamically determined using the real-time information of sensor-equipped machines and other AGVs along with the static ERP data fed into a decision support system.

4.3 Dynamic Reconfiguration and Reconfigurability

Nowadays, the demand for manufacturing products in the market is characterized by small batches and multiple varieties. Therefore, to fulfil this need, the production-line should reconfigure its process paths and recombine manufacturing units dynamically with the least amount of delay in between. Accordingly, the smart factory should adjust product type and production capacity in real-time to keep the machine set up time low. With the use of integrated communication technology and the business systems such as ERP, the reconfigurable production line can generate a large range of different products due to its variability, scalability and schedulability, which is the basis of flexible manufacturing in smart factory. Presently, the problem of the production line is a strong speciality, i.e. an assembly line-based system where each workstation is designed to carry out specialized jobs that can be enhanced by advance planning and control methods. Here, we build a reconfigurable system to simulate the production line and propose a scheme for reconfiguration. The feasibility of the proposed scheme is verified by the manufacturing scenario already available in the ERP system. With the aim to respond swiftly to the market requirements, it is necessary to implement a reconfigurable production line in the smart factory while keeping the manufacturing cost and the waste at the minimum. The dynamic reconfiguration will lead to the following key benefits to the entire manufacturing process:

- It can help to produce smaller lot sizes more economically, making the manufacturing processes more flexible and adaptable. This flexibility is possible due to real-time communication between the machine and products that can take autonomous decisions.
- It can help to improve the manufacturing processes through learning and self-optimizing pieces of equipment that will, for example, adjust their own parameters as they sense changes in the environment.
- The production needs can help to adjust the automated logistics using autonomous vehicles and robots, which can minimise inventory carrying a cost.

5 The Enabling Technologies for Ubiquitous Manufacturing

This section discusses the different technologies that play crucial roles in realising ubiquitous manufacturing.

5.1 GPS

GPS has been widely functional to trace the location of an entity related to the manufacturing. For example, a shop floor manager can use an appliance to retrieve information in real time from different manufacturing processes in different phases, and those are transmitted via GPS, GSM or Wi-Fi.

5.2 RFID

A real-time intelligent advanced production planning and scheduling (APPS) [63] can be realised by creating RFID enabled ubiquitous environment in the manufacturing industry. By using electromagnetic fields, RFID can track tags which comprises information stored electronically of different objects or things. The passive tags can be charged by radio waves obtained from an RFID reader in close proximity. An active tag can have power from a battery and may work hundreds of meters from an RFID reader. A local power source such as a battery can supply power to active tags. Siemens' Corporate Technology [64] researchers have pursued the idea of getting energy into the RFID tag or transponder via radio frequency fields by means of electromagnetic field synthesis by spreading out multiple antennas over an area and focusing their electromagnetic radiation to generate enough energy at a single point to power the transponder.

There are two types of RFID, as follows:

1. Long-range RFID or RAIN RFID: Using the ultra-high frequency band, RAIN RFID is capable of reading tags up to 15 m and thus ideal for use in shop-floor.
2. Vicinity RFID: It uses HF band and can read tag up to 1.2 m and thus, usable for smartphone users.

RFID proposes some noteworthy advantages against other data capture technologies. These are:

- Unique serial number identification.
- Ability to store and modify data.
- Placed on common materials easily.
- Fast scanning, up to 300 tags per second.
- No line-of-sight mandatory as such; they are appropriate to communicate from a long distance (usually, 1–1.5 m).
- On-chip security.
- Kill command for privacy protection.
- Easy integration into printed circuit boards (PCB).

RFID Technology acts a significant role in ubiquitous manufacturing in the following ways:

Supports Optimized Logistics Logistics can be benefitted by active RFID in the following ways [65, 66]:

- Decrease the holding times at gates.
- Larger outcome at peak loading times.
- Enlarged working efficiency at the time of weighing, loading with the automated detection process.
- Logistics facility in real-time.
- Enhanced quality of processes by removing manual paper-based dealings.

Supports Shop Floor Productivity and Quality Control RFID tagged basket is transformed into passive smart manufacturing object (PSMO), carrying the data related to production during the manufacturing phases. Each machine with a stationary reader is transformed into active smart manufacturing objects (ASMOs), enabling them to detect the PSMOs and support workers in running the production logic. Each worker should have an RFID enabled employee id-card for recognizing every individual and his work [63]. RFID technology improves shop-floor productivity and quality control by coordinating raw materials, work-in-progress (WIP) and finished goods as they act as an effective data collector and processor [67]. Decisions can be taken on time without trailing the costly time in production if any fault appears.

Supports Demand-Driven Manufacturing Approach To take decision dynamically according to each customer's need and specification, a system is needed that can integrate with the manufacturing control system and can obtain very accurate information about the location, state and identity of each product to avoid probable problems and delays. RFID laid system has a guarantee to conquer the customization challenge.

Supports Advanced Production Planning and Scheduling (APPS) The wireless manufacturing and intelligent manufacturing are now flourishing as advanced manufacturing technologies which support APPS to extend widely for improving the efficiency and effectiveness of production with the RFID-aided real-time ubiquitous environment. APPS helps a company a lot to cope up with the global competition, to curtail product life-cycles, to lessen time-to-market, to rise product diversity and to please demand while preserving the quality and minimizing the costs by controlling the workers, machines, and materials in real-time.

5.3 Internet-of-Things

IoT connects numerous heterogeneous cyber-physical objects or things like appliances, services, automobiles, farms, factories, even animals with the internet to improve the competence of manufacturing. The network-connected cyber-physical devices can communicate via standard protocols and share data in different environments via the intermediate gateway nodes like modems, routers, switches, and cellular base stations. Integration of real-life smart objects, human, intelligent machines, smart sensors, production procedure and production lines together make the system agile, intelligent and networked, thus making the IoT as Internet of Everything (IoE) consisting of Internet of Service (IoS), Internet of Manufacturing Services (IoMs), Internet of People (IoP). In general, as depicted in Fig. 10, the IoT system involves three chief components:

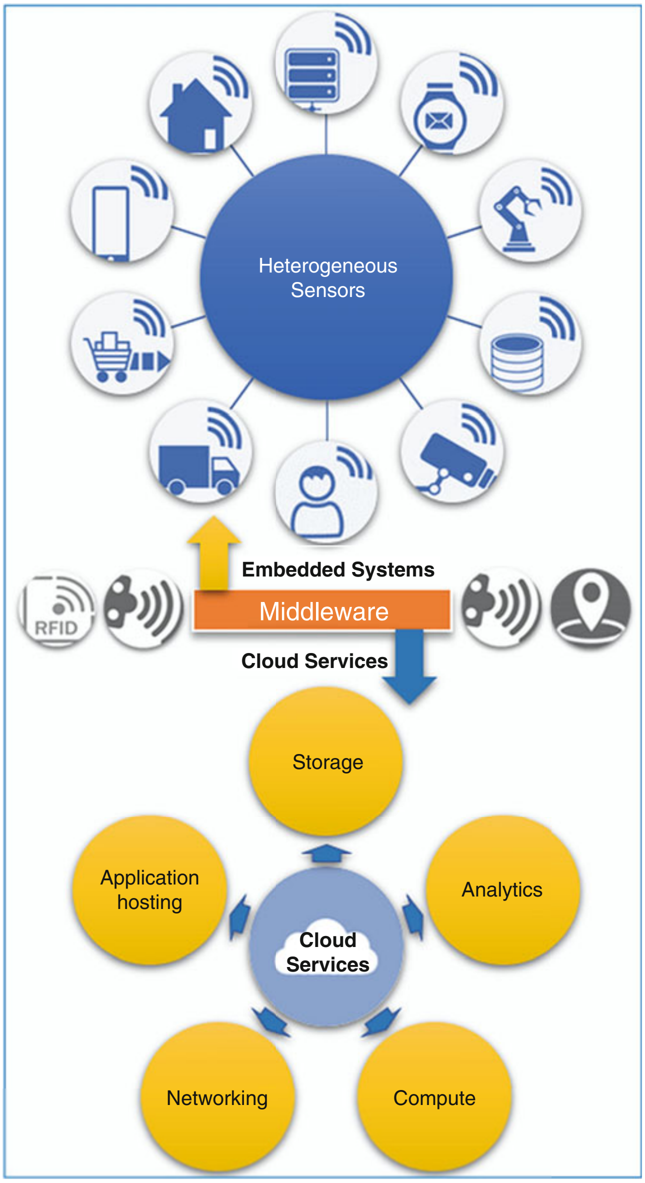


Fig. 10 A typical IoT system components

- **Embedded systems**: Consists of heterogeneous sensors responsible for providing information about the physical entity.
- **Middleware**: Responsible for data aggregation, acquisition control and network connectivity.
- **Cloud services**: Provides comprehensive storage, computation, analytics, application hosting and management mechanisms.

5.3.1 Role of IoT in Ubiquitous Computing

The paradigm ubiquitous or pervasive computing allows computing anywhere at any time. Ubiquitous manufacturing applies ubiquitous computing in the manufacturing industry to establish a "design anywhere, manufacture anywhere, trade anywhere, and at any time" model. Manufacturing products ubiquitously is really tough, but with the advancement in information technology, the science of computing, communication, storing, sensing, and networking, we can now get manufacturing services ubiquitously. Smart factories should have the ability to make use of the continuous flow of data from all related smart objects, operations and production systems. The customers can play an important role as a decision-maker in the production process by giving their choices, preferences and demand.

Ubiquitous manufacturing accentuates mobility through on-demand network access and distribution of manufacturing resources and users. There are three layers in a cloud-based framework: a network of things, cloud computing, and applications [68]. To unify huge amounts of heterogeneous devices and to manage a huge volume of data retrieved from those devices, the service-oriented architectures (SOA) approach is usually adopted on the internet and cloud-centric frameworks. The fundamental technologies of IoT can reshape the manufacturing sector with pervasive real-time sensing, actuation, and commanding data-processing competences.

5.3.2 The IoT as a Production Factor

Based on the smart, integrated and interconnected cyber-physical space, the IoT can assimilate innumerable manufacturing devices capable of sensing, identification, processing, communication, actuation, and networking and thus creating the new business opportunities for manufacturing. IoT-enabled manufacturing (e.g., Industry 4.0 [69], Factory of the Future [70], and Made in China 2025 [71]) is now influencing the world economy greatly.

The following factors involved with IoT have a significant role in manufacturing, as depicted in Fig. 11.

- In the era of IoE, a huge number of heterogeneous physical devices are linked to the Internet, a huge volume of data is taken and gathered by the RFID, sensors, gateways, etc., and communicated through the IoT. In addition, mobile internet, social networking, e-commerce, etc., significantly enlarge the scope of the applications of the Internet.
- The implanting of minute electronics into physical objects and making them interacting is the basis of intelligent integrated cyber-physical infrastructure [72].
- Crowdsourcing through crowdsensing and socialized manufacturing helps to enlarge the scope and dimension of manufacturing [73].

Making twin models to simulate the behaviours of physical objects in real-world is the concept of the digital twin. Therefore, the digital twin is self-possessed of three

Fig. 11 IoT factors responsible for manufacturing

components, the real-world entities, the virtual models for simulation, and the allied data that bond the previous two [74]. The virtual workshop or factory or machine helps to understand the reality in different environments and under different test cases and thus helps to achieve optimal manufacturing (e.g., correctness, constancy, high efficacy and product quality). The data from the different phase of the product lifecycle are gathered and inherited to innovate the next generation product.

5.3.3 Industrial IoT

The Industrial IoT (IIoT) institutes a great surfeit of sensing, computing, storing, and networking, which altogether represent the essential part of industry 4.0 systems. Efficient microprocessors and AI technologies make the products and machinery smarter with capabilities of computing, communication, and control (3C) as well as autonomy with sociality. The IIoT integrates machine learning with clouds, clusters, and grids for Big Data storage, processing, and analytics. In IIoT, end devices continuously produce and convey data streams, which result in enlarged data traffic in the network between device-cloud communication. Big Data analytics is becoming a major contributor to improve intelligence in all parts of IIoT. Figure 12 describes the architecture of IIoT.

The major components of the IIoT are as follows:

- **Sensing systems**: Numerous heterogeneous sensing devices are attached through the Internet to give real-time data continuously.
- **Outer gateway processors**: The computing servers comprise application servers, edge servers, smart switches and smart routers, which are energy efficient and offer reduced latency. The outer gateway processors help to lower bandwidth utilization by reducing and filtering data at the edge of the internet.
- **Inner gateway processors**: These are composed of the micro-clouds, and cloudlet servers exist in the industrial wide area networks (WANs).
- **Outer central processors**: These are the computing servers beneficial in data filtration and data reduction and used for data processing, routing at inner central processors.
- **Inner central processors**: These comprise clusters, grids, clouds, and multi-cloud systems and stay far from the sensing system.

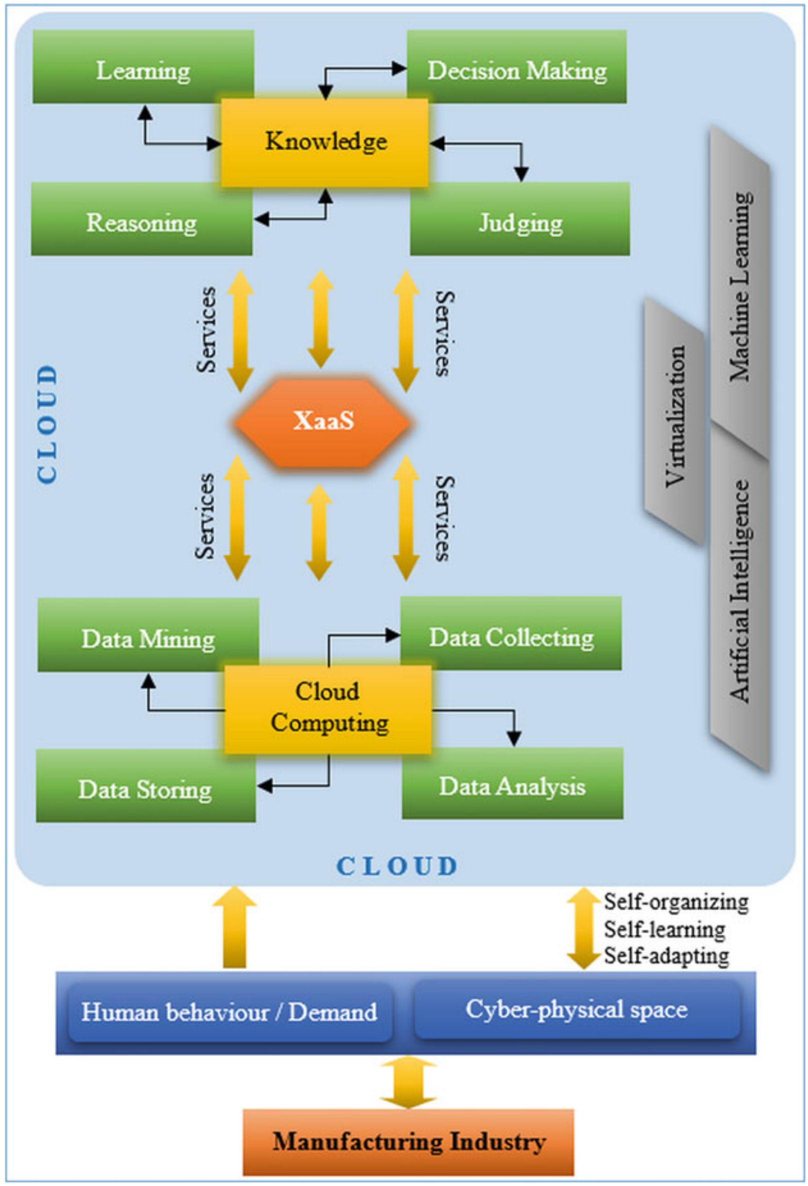


Fig. 12 A general IIoT architecture for manufacturing

5.4 Cyber-Physical Systems

CPS is defined as a technique to interconnect, manage and interact between physical devices and computational applications firmly integrated with the internet and its users. In CPSs, physical and software components are working at diverse spatial, behavioural, and temporal scales and interrelating with each other in a lot of ways that change with the situation. Today's manufacturing world is fully equipped with sensors by which heterogeneous data can be collected for analytics and decision making. The automation can be done in a collaborative way with the development and employment of apparatuses and methods accompanied by the computational and data communication capabilities.

The concept of CPS is the extension of the concept of embedded systems in a way that in the embedded systems the computation is carried by the stand-alone devices, whereas CPS is intended as a network of cooperating computational and physical devices. The data and information processing power of mechatronics is converting progressively the outdated shop floor into an environment to realise elastic, reconfigurable, scalable, inter-operable network-empowered collaboration between distributed embedded devices and arrangements of business processes.

The CPS, when attached with industry, referred as industrial CPS (ICPS), goes hand to hand with multi-agent systems (MAS) and SOA [75]. Often, some complex industrial manufacturing processes cannot be solved with individual capacity or knowledge, and for handling this complex scenario modularity and knowledge sharing are very much essential. A MAS is a loosely coupled network of intelligent agents consisting of different cyber-physical components that interact and communicate to solve problems, take a modular approach, share individual knowledge by decentralizing the functions, providing a ubiquitous manufacturing platform with adaptability, flexibility and reconfigurability.

PLCs or programmable controller programs (PCP) are required to guarantee responsiveness and to develop MAS with more control to deliver intelligence and variation. In the cyber-physical industrial infrastructures, an enormous volume of data is gathered in real-time by numerous integrated sensors that must be analysed in real-time. The real-time analytics applied to Big Data in the cloud computing environment helps immensely to take decisions dynamically in the ubiquitous manufacturing context of Industry 4.0. In addition, the cloud as a communication medium is streamlining the communication process as a whole into the vast heterogeneous industrial manufacturing system.

Since CPS is human-centred technology, communication with humans can be achieved via mobile devices, like smartphones, tablets or wearable devices. The augmented reality technology can be united with things at the time of installation, operation and maintenance of automation systems, thus improving the productivity and competence of operators by providing different relevant information Google Glass has such augmented reality technology that can be used in industrial shop floor environments [76].

Five-level CPS structure, namely the 5C architecture, was proposed as a standard to construct CPS [77]. The levels are as follows:

- **Smart connection level**: With the effective and appropriate installation of sensors, data can be obtained directly from the machines or from the controller or the enterprise manufacturing systems.
- **Data-to-information conversion level**: Relevant information is inferred from the data by using different algorithms and methodologies.
- **Cyber level**: After gathering of enormous information, precise analytics have to be used to fetch additional information, gather additional knowledge from historical information, put on peer-to-peer assessment to get the improved vision over the status of specific machines among the fleet.
- **Cognition level**: Since comparative information and individual machine status is obtainable; a decision support system can be generated to prioritize and optimize the maintaining process.
- **Configuration**: This stage has supervisory control with a resilience control system (RCS) to put on the remedial and precautionary decisions, which has been made at the cognitive level.

5.5 Autonomous Industrial Adaptive and Mobile Robots

Industry 4.0 may be viewed as an emergent of the implementation of next-generation robotics for industrial applications. In his book, The Fourth Industrial Revolution, Klaus Schwab [78], Founder and Executive Chairman of the World Economic Forum, mentions that fourth industrial revolution is not only characterized by smarter and autonomous automation but also based on the complete amalgamation of the cyber and physical extents. It has the potential to renovate not only the way things are produced and distributed but also the dynamics of customer assignation, value creation, management and regulation [79]. The amalgamation of microprocessors and AI makes robots more autonomous, smarter, flexible, adaptive, and social. Adaptive robots are:

- Instrumented, interconnected, and intelligent machines with the capability of data accumulation and autonomous decision making.
- Totally dynamic in nature, i.e. can sense and act on the situation with no direct human involvement.
- Can acquire knowledge by monitoring their own performance, and accordingly update each other time-to-time.
- Proficient to act, based on numerous IoT data and with vision, sensing (touch), speech recognition, collision detection capabilities.
- The computation is done on-board and/or in the cloud.

Adaptive robots are expedient in manufacturing systems, specifically in design, manufacturing and assembly phases because they are autonomous with dynamic thinking capability and response intensive working principle. They are involved in product assembly, treatment of hazardous materials, spray painting, cutting, and polishing, travel and transportation, optimizing logistics, assets, operations, manufacturing tailored products, shaping warehouses, customer engagement and dealings in different places etc.

YuMi (short form of ‘you and me’, human and robot are working together) is a human-friendly dual arm robot created by ABB manufacturing operations [80] and commercially launched on April 13, 2015, at the Hannover Messe in Germany, the world’s largest industrial technology fair. YuMi can feel and see and empowered with safety measures. It has a parts-feeding mechanism, camera-founded part location detection system and gesture control with cooperative, dual arm assembly solution.

Another example can be given as Kuka industrial robots [81] are used in application areas like material treatment, loading and unloading of machines, palletizing and depalletizing, spot and arc welding. Kuka’s lightweight robots are used to accomplish multifaceted assembly line tasks and deliver real-time data in the process of manufacturing, generating cognitive factory environments by means of IoT technology.

An adaptive behaviour to the deformation of a soft object robotic controller was proposed in the paper [82].

The workerbot4 is an industrial robot, created from pi4 [83], has a single-armed service with integrated image processing. The head of workerbot4 is equipped with integrated image processing and facial recognition so that it can identify its operating staff and track people by viewing the entire room. It can verbally communicate status reports, and by means of language recognition software, it can receive verbal instructions.

5.6 Cloud Computing

IoT, Big Data, and cloud computing, along with AI, are empowering factors of Industry 4.0, which basically focus on industrial automation. In current years, the information technology (IT) has pointedly advanced by cloud computing with on-demand self-service, ubiquitous network access, fast elasticity, pay-per-use, and position-independent resource pooling [84]. The clouds with infrastructure management capability are a huge lake of simply usable and reachable virtualized resources like different development platforms, applications, services, hardware which can be reconfigured dynamically to enable self-service, economies of scale and optimum resource utilization.

Nowadays, ubiquitous manufacturing services can be provided with the help of advanced technology of information, communication, sensing, and networking. The cloud manufacturing [46, 85], permits ubiquitous, appropriate, on-demand network accesses to a shared lake of configurable manufacturing resources. Disseminated resources are captured into cloud services and managed in a centralized way in cloud manufacturing [86]. Clients can take cloud services consistent with their necessities. The users of the cloud can request services of all stages of a product life cycle like product design, manufacturing, testing, management etc.

"Design Anywhere Manufacture Anywhere" philosophy can be reinforced by cloud manufacturing with the facility of scalability to the size of business and its needs, ubiquitous network access, and visualization. Abundant information systems are deployed in the cloud, and smart heterogeneous things are coupled to the same cloud. As a result, a new era of IoT and services is created. The cloud helps in superior access to design and engineering resources anywhere and anytime with minimal management effort or interaction of service provider. Ubiquitous access to resources increases scalability, agility, multi-tenancy, and virtualization. Figure 13 describes the working interfaces of cloud computing in ubiquitous manufacturing.

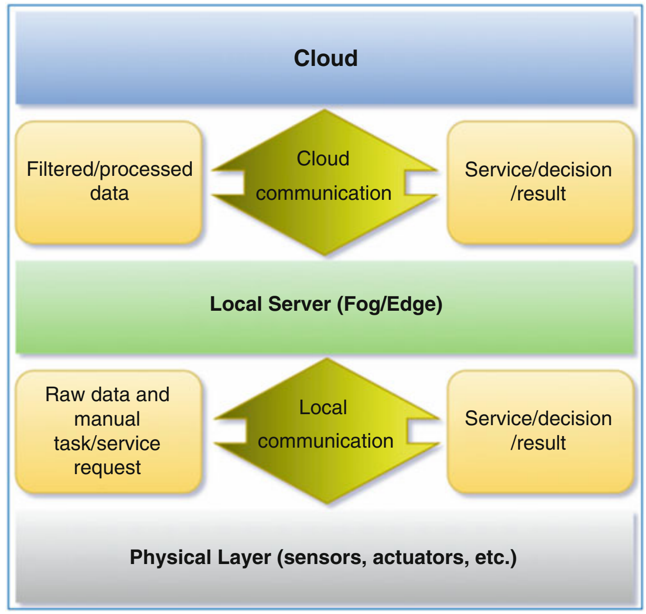


Fig. 13 Working interfaces of cloud computing in ubiquitous manufacturing

Service Provisioning Different virtualised services provided by cloud service providers are shown in Fig. 14 by which distributed collaboration and computing is possible efficiently. Some of the most popular cloud services are:

- **Software-as-a-Service (SaaS)**: By this service, one user can get any software in his own computer by paying a fixed subscription for a specific time period through internet from the cloud service provider (CSP) who is the owner of the license of the particular software application
- **Platform-as-a-Service (PaaS)**: Same as one software application, one whole platform can be provided by CSP to the customer to leverage.
- **Infrastructure-as-a-Service (IaaS)**: One infrastructure such as a server or a machine or a robot or a data center can be obtained as a service without investing for a building or a hardware/software and their maintenance costs but just with the specific service charge to CSP.
- **Desktop-as-a-Service (DaaS)**: A customer can host his entire desktop computing environment with data storage and network communication facility through a CSP.

5.7 Edge Computing

Operational technology (OT), empowering the hardware and software to sense or cause changes in physical processes, events and in the enterprise through direct monitoring and/or control integrated with IT in the IIoT empowers the

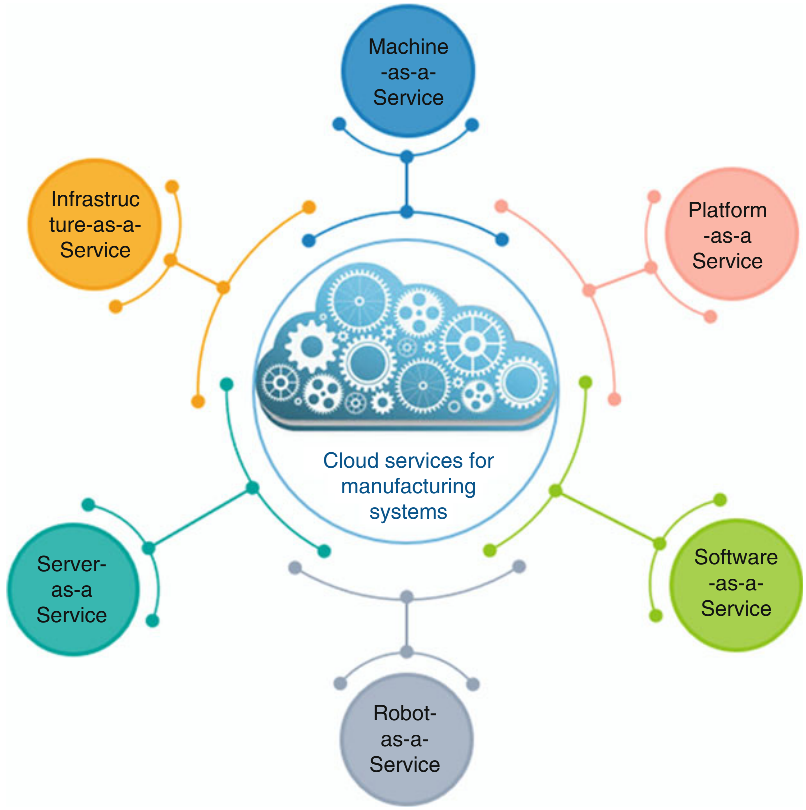


Fig. 14 Cloud services: a large pool of virtualized resources

"smart factory" notion. The smart connected devices with the capability of sensing, collecting, processing and communicating data can regulate and monitor the operational manufacturing environment. This data accumulated by these devices is used for extraction of knowledge, intelligent decision making and forecasting purpose to get more efficient, accurate, cost-effective manufacturing.

The edge consists of smart entities/things involved with the manufacturing process, as depicted in Fig. 15, resources and smart products used as a smart agent in MAS. A distributed intelligent agent-based model for Big Data accumulation and analysis is presented in [87]. The low-layer agents provide information about the work-in-progress, operational state of resources and availability or quality inspection results and also can allocate job or rescheduling tasks. The upper layer agents deal with time-ordered data, analyse the covariance of multiple monitored metrics and huge historical data. Then, that gathered knowledge is used for the optimization of universal cost functions, reconfiguring resource teams, forecasting actions/events, assessing precautionary maintenance.

Despite moving all data over the cloud for processing, some operations can be done close to the IIoT device, i.e. at the edge of the network. An aggregation node [88], as depicted in Fig. 15, with IoT gateway, enabled with the software platform is required to process data directly on distributed edge devices. This process helps to simplify data transmission as well as minimizes latency. Edge computing offers edge services close to the source of data to encounter the different critical situations in real time optimization, security, agile connectivity issues.

5.7.1 Fog Computing for IIoT

The amount of data from the sensor-driven world can be measured in the petabytes. Routing the Big Data generated by all the edge things like loads of connected sensors for industrial control systems (ICSs), self-directed drones, industrial robots, streaming of video surveillance cameras casing shop floors etc. to the remote cloud would congest the internet backbone [89]. Traditional IT is approaching to OT environments in the IIoT scenario, but the main challenge in this path is to maintain the required volume, latency, mobility, reliability, security, privacy, and network bandwidth. This requires, in turn, a middleware layer with some computational and communication abilities between the edge and the cloud level.

Fog is a distributed architecture that ties the cloud and the connected devices that don't need persistent connectivity with the cloud. Fog computing outspreads cloud computing to the edge network. Fog works closer to IoT sensors and actuators, where the data is generated and used. The fog computing is an architecture which decentralizes the

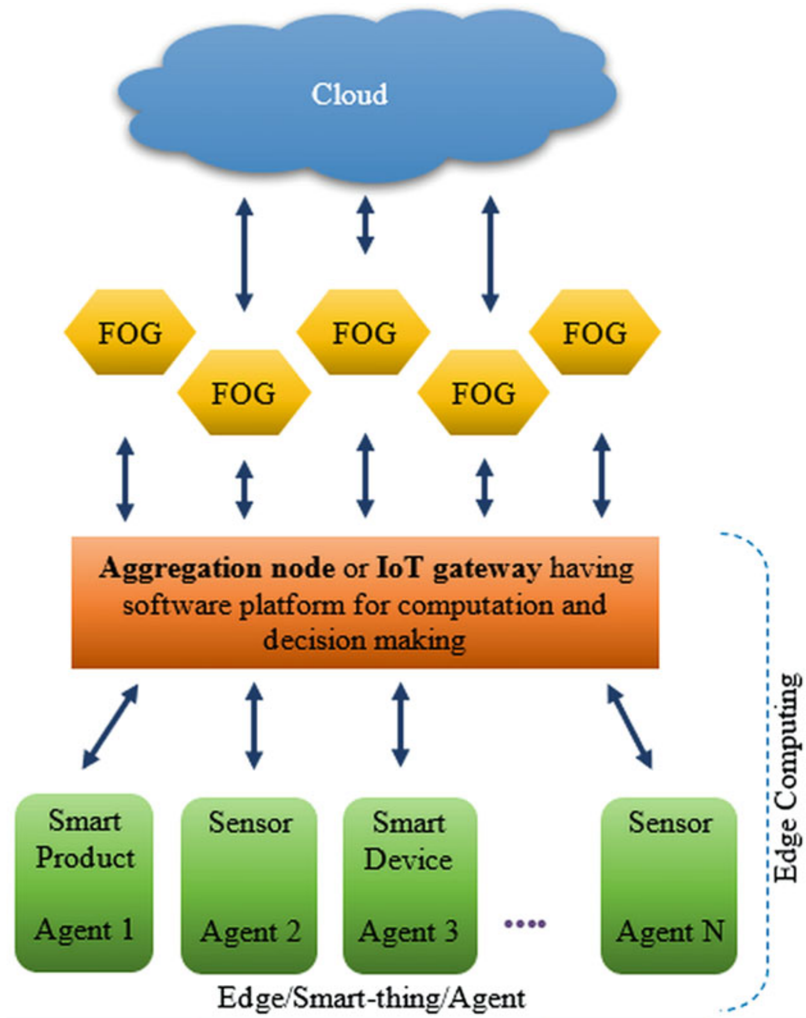


Fig. 15 Edge computing architecture

computing structure including data, applications and networking resources from remote data centres towards the edge devices. To reduce the communication and service deployment delays, it is necessary to complement the cloud through the distribution of the computing-plus networking resources to edge node level.

The fog computing trusts on interconnection capabilities among nodes, whereas edge computing deals with isolated edge nodes. The fog [90] connects the resources and data sources between devices exist in the edge in cloud-to-sensor, and function-to-function or peer-to-peer hierarchies whereas edge computing lean towards to a small number of top-down layers often attached with simple protocol gateway functions as depicted in Fig. 16. If it is required to make real-time decision-making in emergency critical situations, fog nodes can take a decision by its own by not routing it to the cloud. This helps to solve potential latency issues, queue delays, or network/server downtime. The fog nodes can add more functionality of production planning, operation, modification, supply chain maintenance etc.

5.7.2 Benefits of Fog Computing

The basis of fog computing architecture and its benefits are as follows [91].

- **Security**: Since, things-to-fog (T2F), fog-to-fog (F2F) and fog-to-cloud (F2C) connections can be made dynamically (as depicted in Fig. 16) across various applications, security is of utmost importance.
- **Scalability**: Processing of information mostly occurs locally in fog computing, thus reducing the amount of data required to convey from a shop-floor to the cloud. This reduces cost and computational capacity, network bandwidth, and the fog networks' storage size can be adjusted as per demand to maintain overall production efficiency.

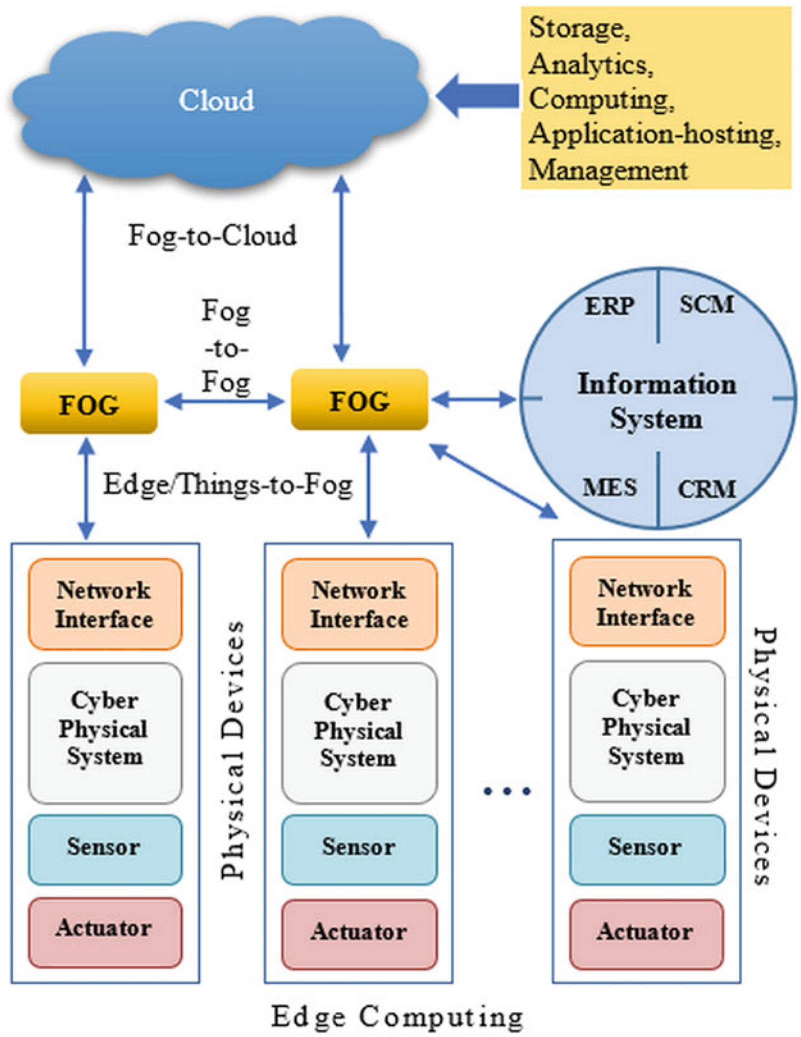


Fig. 16 Edge-Fog-Cloud architecture

- **Openness**: Different application programming interfaces (APIs) can be shared through the fog to aid the factory's production equipment, to link up with remote maintenance service providers.
- **Autonomy**: The autonomy provided by fog computing allows the manufacturer to perform designated actions, even when the cloud is unreachable or overloaded. This enhances high reliability, availability, and serviceability in critical production environments and maintenance functions.
- **Agility**: Fast localized and intelligent decision-making is possible by fog computing within a fog system. A minor fault in any machine or any new requirement can be spotted and addressed instantly, thus enabling predictive maintenance which decreases factory downtime.

5.8 Real-Time Communication

Real-time communication supports communication without transmission delays, using peer-to-peer architecture. The wireless communication technologies can provide connectivity to robots, machinery, or workers, and deploy the flexibility by lessening and significantly simplifying the need for cable installation in plug and produce setups. WSN [92] is significant in manufacturing because the installation and maintenance of wired set-up in the shop floor is difficult and also incurs much cost. Industrial WSN (IWSN) enjoys the advantage of easy and effective arrangement over the required range, maintained by battery or wireless charging. The communication infrastructure has the following features [93]:

- **Ultra-low latencies**: The network is able to process huge data with an extraordinarily low tolerance for delay or latency.
- **Ultra-high reliability**: Flexible adjustment as per the need and capability of automatic fault monitoring make the system reliable.
- **Energy-efficient**: The system can go to sleep by virtue of software scheduling when it is not in use, thus gaining energy efficiency.

- **Ultra-low communication costs**: Different sensor-based hardware and software are deployed for less power consumption, downtime reduction and enables JIT communication and thus reducing overall costs.
- **Efficient data distribution and management**: Group-based WSN is emerging to better data distribution, communication and management.

5.8.1 Software-Defined Networking

In today's era of high-tech networking, the increasing demand for networking, diversification and complexity of the function is causing traditional network architectures gradually to become unsuitable for today's enterprises, operators and end users, motivating an evolution from traditional networking to new network architectures which has two parts the control plane and the data plane. Software-defined networking (SDN) [94] has the advantages of programmability, automation, and network control, allowing operators to establish extremely scalable and flexible networks while adapting to changes in the network environment.

5.8.2 Cognitive Radio Network

Cognitive radio network (CRN) [94] is a novel wireless communication technology that defines a primary user with priority access to a particular band of resources in a wireless network and allows open secondary users to use unlicensed resources; the wireless node be able to sense the surrounding radio spectrum while controlling use of the band. A CRN can observe the network environment and identify available idle frequency bands.

5.9 Web Services

A web service is as a self-reliant virtually unified single logical system, composed of heterogeneous interacting software modules accessible through the Web over the Internet, accomplishing responsibilities, resolve problems, or conducts transactions for a user or application. The IoS [95], is an important support for Industry 4.0, coupled with IIoT and CPS and fog-cloud computing technology. SOA, through the cloud-based structure is essential for factory-to-factory interoperability, cross-layer collaboration, cross-site application between heterogeneous industrial systems.

5.9.1 Smart Factory Web Architecture

Smart factory web (SFW) architecture supports plug and work abilities for physical resources to protect data and service integration in cross-site application situations [96]. SFW architecture involves factory-thing device management, factory-thing data management and analysis, and service interface. It provides an open API for the SFW portal as well as for enterprise information system (EIS) applications. The smart EIS, such as the manufacturing execution system (MES) or ERP system, can be tangled in SFW involving various devices, sensors, actuators, control systems such as PLC, and distributed control systems (DCS) in the physical platform of the edge tier.

5.9.2 Amazon Web Services

Amazon Web Services (AWS) [97] is a safe, agile, and scalable platform having power of data analytics and machine learning thus gaining operational efficiency, helping to design and verify new products, creating new smart-product business opportunities, optimizing production and scale effortlessly to meet increasing demand as well as improving security position and lowering IT and OT cost structure too.

AWS helps ubiquitous manufacturing in a smart factory by:

- Improving quality and machinery uptime.
- Enabling access to heterogeneous real-time data to expand overall equipment effectiveness (OEE).
- Empowering AI and ML for real-time data. analytics, prediction and decision making.
- Generating cloud security and providing robust disaster.

5.10 Virtualization and Virtuality

In computing, virtualization is the course of generating a virtual or logical form of a device or resource like a server, operating system, network, storage place or one application program. For developing the ability of self-optimizing, self-configuring and self-diagnosing abilities in a dynamic way in a smart factory environment, the resource virtualization or formation of digital twins are very much significant. Digital twins are virtual replicas of physical devices that can be used to run simulations before actual devices are built and installed. Simulation of a physical object by digital twin in real-time suggests visions into performance and potential problems of factory, shop-floor or warehouse. Virtualization helps to create a logical copy or digital twin of the physical machine or original factory floor or warehouse digitally by merging sensor data acquired from monitoring physical processes and equipment. The virtualized view of operations visualized through a 3D interface helps to monitor physical processes and to manage complexity, optimize processes and reduce equipment downtime. A digital twin could even assist as a prototype itself before any physical version is created. As more complex "things" become connected by virtue of IoT with the capability to produce data, and having a digital correspondent by the benefit of the virtualization or the digital twin technology has moved the ubiquitous manufacturing in industry 4.0 to a greater height. A digital twin helps to identify unbearable deviations from ideal settings for business optimization, thus improving quality and realizing greater efficiencies in the physical world [98].

Oracle IoT Cloud [99] offers the most comprehensive implementation of the digital twin through:

(a) **Virtual twin**—A virtual depiction of a physical device or an asset with observed and desired attribute values and also using a semantic model
(b) **Predictive twin**—Building of an analytical or statistical model containing the entire business scenario and generating contextual data for analysis and prediction by using a machine-learning technique.
(c) **Twin projections**—Integration of predictions and insights with back-end business applications.

Different resources can be virtualized. Some of them are mentioned below:

- **Storage virtualization**: The unification of manifold network storage devices into a virtual one which seems to be a single storage unit. Storage virtualization or software-defined storage or a virtual storage area network (SAN) [100] is the merging of multiple physical storage arrays from SANs and giving the impression as a single virtual storage device.
- **Server virtualization**: It is the partitioning of a physical server into smaller virtual servers to enhance the capability of management.
- **Operating system-level virtualization**: Same as the server virtualization technology at the operating system (kernel) layer.
- **Network virtualization or network function virtualization**: Network virtualization can be like virtual machine services, as it can be used to start network services conveniently and rapidly. Network virtualization [94] is currently used in networks in support of packet delivery, routers, data transmission and other network functions, and is managed by general network hardware and control software. Administrators can establish the required virtual functions of the network on a virtual machine, such as by adding a firewall or intrusion detection and prevention systems (IDPS) to the network. Installation of the required networking capabilities in the network can reduce manpower cost and time. For example, in a factory environment, each department may have its own independent network environment, or different projects may have to be able to use part of the network without external interference. Network virtualization slicing technology enables a physical network to be cut into multiple virtual networks for various slices, enabling the effective allocation of network resources to users.
- **Application virtualization or application service virtualization**: Application virtualization helps to run an incompatible code in non-native operating system environment on a local machine simultaneously.

5.10.1 Virtual Reality

Augmented reality and virtual reality are two pillars to implement virtualization in Industry 4.0. The augmented reality is concerned to merge digital elements with real-world activities. Virtual reality offers a computer-assisted simulation tool to recreate a real-life environment. With the rapid development of new technologies like RFID, sensors, RTLS, smartphones, etc., which enabled real-time data flow and integration of CPS with augmented and virtual reality techniques help a lot to create a simulation to achieve a smart design paradigm.

5.10.2 Virtual Control of Robotic Arms

To achieve a more speedy, accurate and cost-effective production system, the manufacturing industry is shifting from human workers to intelligent robots. The use of IoT and information and communication technology (ICT) with AI, cloud computing and advanced information analytics technology are providing such intelligent industrial robots which can be controlled from the remote end to the smart factories. Industry 4.0 also allows a progression from automated embedded system-based manufacturing to CPS-based manufacturing equipped smart sensing, actuating, decision making and communication capabilities. The self-estimation capabilities and self-consciousness of CPS allow intelligent production capabilities on the factory floor by monitoring physical processes, making a digital twin and making decentralized decisions.

The industrial robots are machines with embedded intelligence which help the manufacturing industry in the following ways:

- **More accurate, more efficient and more time specific than human labour**: Some critical manufacturing works which are beyond the capacity of human labour can be done by robots with a specific accuracy, efficiency and within a specific time interval.
- **Reduction of labour force injuries during the production process**: As the robots can be employed in various risky critical manufacturing processes, it can reduce labour injuries.
- **Increases efficiency by a collaborative effort of human and robot**: The collaborative tasks of robot and human can increase the efficiency level of manufacturing a lot.
- **Increases flexibility and reconfigurability in smart factory environment**: Assimilation of industrial wireless networks, cloud, and IoT with smart artefacts like robotic machines is absolutely vital for dynamic decision-making capability, flexibility and reconfigurability of smart factory.

- **Autonomous detection of fault and optimization**: Industrial robots can sense problems in product performance and can resolve it by using its intelligence in many cases. Modelling, controlling, self-assessment and failure recovery of production processes and working environment can be achieved, and goal-directed decisions can be taken autonomously by robots in a dynamic manner.

5.11 Distant Operation

With the advancement of IIoT with the cloud-based approach, the whole factory set up is now semi or fully automatic. The manufacturing process can be checked from, and the machines can be controlled by robotic arms or hand gestures or voice recognition techniques from a remote site. In risky manufacturing environments, virtual control is just feasible solution to deal with tremendously high or low temperatures or to handle unsafe and unreliable apparatus.

5.12 CNC Machines

The CNC [101, 102] has a vital role in intelligent manufacturing that includes digitization, networking and information technology in the core manufacturing industry. The CNC system of a machine tool includes the control unit, and the motion-control system such as the servomotors, drives and axis positioning devices. Instead of causing motion by manually, CNC machines permit motions to be activated by servomotors under the control of the CNC and directed by the respective program. The motion type, the sequence of operation, the axe movement, the quantity of motion and its rate are also programmable.

The main features of CNC technology, which helps a lot in intelligent manufacturing are as follows [103]:

- **Improved automation**: CNC machines can be operated without an operator; thus, can avoid operator exhaustion, human error, and can maintain reliable and expected machining time for each workpiece.
- **Increased productivity with consistency and accuracy**: Several alike workpieces can be easily formed with precision and consistency, thus increases productivity.
- **Flexibility and re-usability**: Since all are programmable, the changeover can be done very fast and recalling of the same program can also be done very easily.
- **Short setup time**: It helps in today's JIT requirements.
- **Faster and more precise manufacturing**: A high-performance hardware architecture and intelligent control algorithms as well as premium class drive and motor technology class ensure the highest dynamic performance and machining precision.
- **Improved customization**: Dynamic decision making on the basis of customer demand is possible by intelligent computation.

In recent times, the CNC systems like HNC8 [104], FANUC [105], and Sinumerik [106], have adopted the front-end structure which takes on non-real-time or semi-real-time tasks, and back-end structure performs real-time numerical control machining. Both are located together with a machine tool and co-operate with each other via a communication bus (e.g. CAN, RS-485, or RS-232) or an intranet [101].

In cloud-based CNC systems, virtualized resources such as virtual operating system, virtual memory, and virtual hard disk space are provided to support the enhanced front-end which can then act as the front-end-as-a-service (FaaS) [101].

The FAAS approach has four main advantages:

- By using cloud computing technology, it provides on-demand resources or services for the back-end and receipts benefit of virtualization technology for better obtainability of cloud resources.
- Dynamic resource allocation can be done in a better way in reply to an increase in demand.
- Since the cloud provides a more affluent environment, supporting heterogeneous software [e.g. computer-aided design (CAD), computer-aided manufacturing (CAM), and Computer-aided engineering (CAE)] and user-defined applications, users can access those applications in the cloud-enabled front-end and run these applications to deliver smart service area for the back-end.
- The cloud layer employs high-end servers which give powerful computing resources, including CPUs and storage, to the cloud-empowered front-end.

The back-end, positioned in a workshop, mainly comprises of a servo controller, PLC, a numerical control unit (NCU) accountable for real-time tasks casing position tackling, speed scheduling, interpolation arithmetic etc. The client offers operators with a collaborative interface from a PC, a laptop, or a smartphone.

5.13 Epistemology and Ontology

Adoption of new industrial practices enabled with IIoT, AI and ML technologies in design, planning, decision support system optimization, etc. throughout the life cycle of manufacturing gives birth the need of an intelligent knowledge management system to acquire, represent, and extract manufacturing knowledge used in-factory automation in a machine-interpretable way. Epistemology is the philosophy which decides which knowledge should be acquired, the process of acquisition, and how that knowledge can be delivered dynamically with the ubiquity, context awareness and pervasively.

Ontology is a method for representing manufacturing knowledge which can be used to configure, coordinate and supervise the manufacturing system in a way which can be interpreted by a machine. A manufacturing ontology can be specified for the entire production life cycle. In cloud manufacturing, where agent-based SOA is prevalent, ontologies play an important role to provide a shared, machine-interpretable vocabulary for exchanging information among isolated actors. Ontology can represent heterogeneous dynamic context data about manufacturing. Ontologies empowered by description logics (DL) and supported by standard languages, can be used extensively for the representation of knowledge in structured in computable form and also for reasoning purposes thus promoting the exchange of knowledge and its re-use.

MASON (MAnufacturing's Semantics ONtology) [107], ADACOR Ontology [108] are the examples of manufacturing ontologies. The Semantic Web Rule Language (SWRL) [109] is a language powered by Web Ontology Language (OWL), developed by the World Wide Web Consortium (W3C) and DL is used to express rules and logic. SPIN (SPARQL Inferencing Notation) [110] is another language with capabilities of meta-modelling can overcome the drawback of SWRL. Manufacturing Resource Capability Ontology (MaRCO) [111] based on OWL, has the ability to model and infer information about the collective capabilities of cooperating resources.

5.14 User-Centric Pervasive Environment

The IIoT has the capability of self-learning to respond in an intelligent way to realize user requirements through context awareness, to deal with open scenarios driven by the complex and wide-ranged different human behaviours. The virtual/augmented reality based systems are dependent on HMI and collaborations thus resulting of a unification of human sense, sentiment and emotion to concept an advanced virtual collaboration environment, where users can feel the pervasive presence of human-machine at work in the same physical site.

6 Allied Technologies

Industry 4.0 has witnessed the emergence of several advanced manufacturing technologies which are closely related to ubiquitous manufacturing. This section discusses some of such technologies.

6.1 Cloud Manufacturing

Presently the manufacturing sector is experiencing a new paradigm shift from existing manufacturing practices to the service-oriented business model—Cloud Manufacturing, in which the manufacturing capabilities and resources can be shared on a cloud platform. Presently the manufacturing sector is experiencing a new paradigm shift from existing manufacturing practices to the service-oriented business model—Cloud Manufacturing, in which the manufacturing capabilities and resources can be shared on a cloud platform. X. Xun described cloud manufacturing as [86]:

> Networked manufacturing model that exploits on-demand access to a shared collection of diversified and distributed manufacturing resources to form temporary, reconfigurable cyber-physical production lines which enhance efficiency, reduce product lifecycle costs, and allow for optimal resource allocation in response to variable-demand customer generated tasking.

The new technology combines recent technologies such as cloud computing, IoT, service-oriented technologies and high-performance computing to remove the bottlenecks of the manufacturing practices [112]. Cloud manufacturing can be seen from both viewpoint: (a) the direct application of cloud computing techniques to manufacturing and (b) manufacturing-oriented cloud computing [113].

The cloud manufacturing process revolves around the following three groups (as shown in Fig. 17) [114]:

(a) **Consumer or end user**: User may be referred to an individual or a large group who create the engineering requirement of a product but don't have the capabilities to so in a cost-effective manner. The engineering requirements with final conditions are then provided to the cloud-based applications by the users.
(b) **Application provider**: The application provider act as an intermediator between the end user and physical resource provider. Its primary task is to manage and control the cloud-based application layer by interpreting user requirements, transforming them into data required for product development.
(c) **Physical resource provider**: The physical resource providers (PRPs) accept manufacturing data as input from the application providers and produces finished

Fig. 17 Overview of cloud manufacturing

product in conformity with user conditions as output. Manufacturing equipment are owned by the PRPs having the expertise in utilizing the machines efficiently. The PRPs may be distributed over a wide range of geographic locations and are connected via cloud manufacturing network.

6.2 Cloud Robotics

Robots are in use for the past few decades to help mankind to perform various difficult tasks in an efficient and precise way. In an industrial environment, they are primarily used in manufacturing units to perform tedious, repetitive or hazardous tasks in a precise manner. Use of robots provides competitive advantages by improving the product quality and reduces the cost per product while providing safety to the workers. For instance, in the automobile industry, robots are deployed for assembling, welding, painting, and packaging where human involvement otherwise would be hazardous, inefficient, and inaccurate. The networked robotic system offers an environment in which the robots are connected via wired or wireless networking topologies and are empowered to provide an improved functional range. They work in a collaborative environment to complete a task and are capable of sharing information within themselves.

Cloud robotics is a new dimension in robotics which has the potential to work beyond networked robotics. In networked robotics, the computational capabilities are limited to respective robots only, and the information sharing is restricted to the network only. Due to the advancement in cloud computing, cloud robotics has the potential to remove some of these bottlenecks and can offer more intelligent, efficient and cost-effective solutions [115]. In cloud robotics, the high complexity computing process is transferred to the cloud platform through communication networks, thereby reducing the computational load of individual robots. Figure 18 presents the system level architecture of cloud robotics. The top-level block represents the cloud infrastructure, which includes a number of high-end and proxy servers, large databases, and other associated components. The lower block comprises of various types of mobile robots, auto driven vehicles, industrial equipment, and other physical machinery as required in the present-day industry [116].

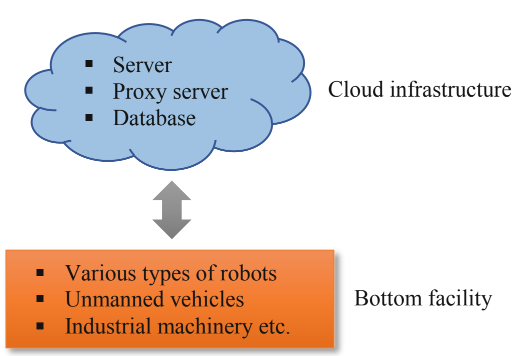


Fig. 18 System level architecture of cloud robotics

With the evolvement of Industry 4.0, the cloud robotics popularity in various industrial application areas such as simultaneous localization and mapping (SLAM), grasping, navigation, etc. have been increased by manifold [116]. SLAM deals with exploring the unknown environment and demands high-end on-board computing facility. Grasping of unknown objects with high precision in the industrial scenario requires huge data processing and computing in the background. Similarly, during local and global navigation, large numbers of parameters are to be taken into consideration, thereby demanding huge storage and computing capability. Cloud robotics, owing to its huge cloud-based computing and storage capability, fits perfectly well in such application areas.

6.3 Manufacturing Grid

The complexity in product manufacturing is increasing day-by-day due to the demand of buyers for cost-effective and quality products. This requirement forces the industry houses to make use of its own resources and the resources available elsewhere, employing networking. Grid technology has rapidly become popular in scientific computing, large-scale database management, and collaborative works [13, 117]. The concept is very new in the field of manufacturing and is termed as Manufacturing Grid (MGrid). The principal idea of MGrid is to organize various types of resources spread over different geographical regions, organizations and other entities. MGrid offers various manufacturing services to users more conveniently than before. It can support specialized manufacturing requirement of business enterprises through networking. Heterogeneity and regional distribution of resources are not made visible to the end user and is provided with a feeling as if all resources are available to them locally. It is expected that the enterprises and even individuals can obtain different manufacturing services on the Internet with ease using MGrid.

6.4 Internet Manufacturing

Industry 4.0 is the evolvement of new digital industrial-technological transformation with the support of various technological advancements like cloud computing, IoT, Big Data analytics, cybersecurity, etc. In this environment, sensors, machines, workpieces, and IT systems are connected to each other over the Internet, which spread across different regions. Interaction between the connected systems takes place using standard internet protocols and have the ability of self-configuration, prediction of failure, and adapt to desired changes [118]. The idea behind internet manufacturing or cyber manufacturing [119] is to enhance the production of high-quality goods at a reduced cost, which in turn promote industrial growth and change the workforce profile. Cyber manufacturing utilizes a systematic approach for manufacturing operations with the involvement of internet technology to achieve the functional objective of an enterprise with increased productivity and reduced downtime. It performs better than its predecessor, i.e. e-manufacturing in various aspects like learning ability, scalability, accessibility, etc. [119]. Lack of standard, handling of Big Data, and cybersecurity are some of the challenges to be addressed to make internet manufacturing more popular and acceptable to the industry.

6.5 Global Manufacturing

A Global Manufacturing system is defined as a company that produces various components, assemblies, and final products for another organization by utilizing the raw material, infrastructure, cost, and a well-designed supply chain network that ma spread over a different part of the world. Manufacturing units spread over different parts of the world require networking to synchronize the production and other related activities among them. Global presence and networking among them help to remain them ahead of other local competitors in terms of cost, quality and technology. Better coordination in terms of research and development (R&D), design of product and process, manufacturing, engineering, marketing, supply and distribution, etc. among these geographically isolated units helps to perform better than their local competitors [120]. The multinational corporations (MNCs) are an example of such a section of enterprises.

The supply chain network in the context of global manufacturing includes [121]:

> Suppliers, factories, subcontractors, warehouses, distribution centres, and retailers, through which raw materials are acquired, transformed, produced and delivered to the end customers.

Instead of an individual unit, a group of business entities are responsible, in global manufacturing, for procurement, manufacturing, and distribution activities. Availability of ubiquitous high-bandwidth internet connectivity paves the path of strong supply chain management network for global manufacturing. The ERP system has an important role to play in the context of global manufacturing. It helps to deal with the complex management issues, supports to integrate different data related to regular activities like production, operation, distribution, finance, accounting, sales, purchase, and human resource management of an organization. In addition, ERP helps an organization to implement the advanced business process [122].

6.6 Virtual Manufacturing

The Virtual Manufacturing process is bringing a revolution in the manufacturing sector. It is a process which utilizes computer-aided design environment to manufacture products. It provides a computer-simulated environment of the actual manufacturing process with the help of virtual reality [123]. It has the capability to provide a better understanding of a process without making of prototype models, reduce time in product and process development cycle, eliminates material waste and faulty design. In addition, the virtual manufacturing process helps to train a new operator quickly in comparison to the conventional manufacturing system, thereby reducing the wastage of machine time.

Various web-based technologies support the virtual manufacturing environment [124]. Web-based virtual systems are now available to facilitate the design of machine tools, performance evaluation of these tools and the entire manufacturing process. To animate different manufacturing processes, web-based CAM subsystems are developed which are capable of displaying the real-time manufacturing process. Virtual manufacturing network (VMN) helps to interconnect various production companies to develop one virtual production system and to execute a production order. The VMN can dynamically configure and re-configure different manufacturing units to accomplish a production task, including its volume and specification [125]. The VMN facilitates the sharing of spare capacity and expertise to produce good quality products.

6.7 Lean Manufacturing

Lean Manufacturing is a systematic approach to minimize waste from production without compromising the production capacity and quality. It actually works relentlessly on eliminating waste from a manufacturing process. In the past, Toyota Motor Corporation has implemented lean manufacturing successfully and displayed appreciable enhancement in productivity and decrease in wastes in its firm. Since then, other manufacturing firms across the globe adopted the lean manufacturing approach to increase their productivity by reducing waste [11]. Implementation of lean technology is attached to many challenges and roadblocks like proper communication, monitoring, integration, etc., due to which some of the industries obtained partial or no success.

The main objective of lean manufacturing is to create a well-defined sequence of processes to manufacture the finished products at the desired pace of customers with minimum or no waste [126]. Inclusion of lean manufacturing in Industry 4.0 is an important research issue for quite some time. Automation in production has played an important role in this integration. Implementation issues involving supplier, customer, process and control, and human factors of lean manufacturing in the industry have been very well addressed by technologies associated with Industry 4.0.

6.8 Agile Manufacturing

Agile manufacturing refers to an approach which enables an organization to develop an internal process and supporting environment to leverage a competitive advantage over its competitor in the fast-changing market place [127]. Such an organization can respond quickly to the changing needs of the customer and market still maintaining the consistent quality at a competitive cost. Development of manufacturing support technology is considered to be the key factor in implementing agile manufacturing process which permits the designer, the production people and the marketing team to share a common database of parts and products, data on production capacity and associated problems. Initial identification and solution to the problems will be cost effective as compared to the cost of correcting quality when the problem moves in the downstream and become complex.

Agile manufacturing empowers an organization to work in a highly competitive market scenario [128]. Timely incorporation of small changes in manufacturing a product as per market need and feedback offers a huge advantage in the long run in terms company's reputation among the customer. In order to implement agile technology, the organization should have a strong network of suppliers and related company along with an internal team of employees to deliver product effectively as per the changing need of the customers. In the context of the global economy, a company which can adapt to the quick changes as per the market need will be preferred by the customer and can sustain very well in comparison to the others.

6.9 Additive Manufacturing

Additive manufacturing refers to a method of production used to produce a small quantity of specially designed products that offer construction advantages, such as complex, lightweight designs [129]. It is also known as 3D printing technology which is mostly used to prototype and produce products in small quantity. The technology is continuously being improved to embrace wider application area such as automobile, various sphere of engineering and technology, medicinal and biological systems, and food supply chains [130].

Additive manufacturing is capable of providing a layer-wise additive method to manufacture products having complex design and shape with a large variety of materials. Reduced cost of programmable controllers, lasers, inkjet printing, sophisticated CAD software, etc. catalysing the further growth of the additive manufacturing technology. As far as the industrial perspective is concerned, it has the capability to influence the traditional system of production models in terms of machinery, assembly processes, and supply chains of industry. Design flexibility, the realization of complex geometric shapes, dimensionally accurate product manufacturing, removal of multiple parts assembly, time and cost efficiency in production run are some of the vital capabilities of additive manufacturing which outweigh the conventional production system [130].

Additive manufacturing is considered to be one of the essential ingredients of Industry 4.0. It empowers the manufacturing sector to embrace the non-conventional approaches successfully. Additive manufacturing is expected to be the key technology for manufacturing highly customized products due to its ability to design and produce sophisticated goods, thus offering the highest level of customer satisfaction [131]. Metal additive manufacturing is one of the latest trends in additive manufacturing in which different types of metallic components can be manufactured using aluminium, titanium, stainless steel, etc. which can replace their conventionally manufactured counterparts.

6.10 Chaordic Manufacturing

Conventionally, complexity is considered as a negative phenomenon and is regarded as a problem to be minimized, controlled, or if possible, to be removed [132]. In modern manufacturing system in order to create novelty, complexity is nurtured instead of elimination. In this context, a new way of thinking known as Chaordic systems thinking (CST) is developed. CST is an approach to design a complex organisational system that considers an enterprise not as a fixed structure but as 'flow'. The word Chaordic is derived from chaord, which is a combination of two wordings chaos and order. Chaos is treated as [133]:

> A condition of disarray, discord, confusion, upheaval, bedlam, and utter mess arising from the complete absence of order.

Chaos theory is very effective in describing and explaining the behaviour of the complex, dynamical, non-linear, co-creative, far-from-equilibrium systems. CST is also defined recently as a qualitative framework in the complex domain which integrates and generalizes the prevailing ideas from numerous disciplines, instead of developing fresh ideas.

7 Future of Industry 4.0: The Stride towards Industry 5.0

Remember the struggle for survival of Will Smith in the film "I, Robot"! Yes, it's coming—embrace it—Industry 5.0; but without the devil robots. This upcoming industrial era is all about more cooperation and interaction between men and machines; the robots making human's work better and faster. In Industry 5.0, the robots will be more collaborative; hence, they are termed as "cobots". These new generation robots are cheaper, more mobile, and more flexible than their earlier versions. These cobots can work safely alongside human workers without requiring any safety cage. Introduction of cloud robotics will allow workers to control robots remotely eliminating the need for the physical presence of the operator. The offered flexibility and efficiency will make manufacturing truly global. The concept of Robotics-as-a-Service (RaaS) will allow the small companies pay-per-use without an upfront investment on robotics [134]. All these will be well-supported by the launching of high-speed 5G networks which, along with the widespread use of wearables on the factory floor, will take augmented reality in manufacturing to a new level. Moreover, Industry 5.0 will see the workers be more creative and products to be more customer-centric, i.e. customised [135]. In spite of these developments, it is worth mentioning that Industry 5.0 will be the upgradation of Industry 4.0 and not entirely new paradigm. The highlights of the future Industry 5.0 are mentioned in Fig. 19.

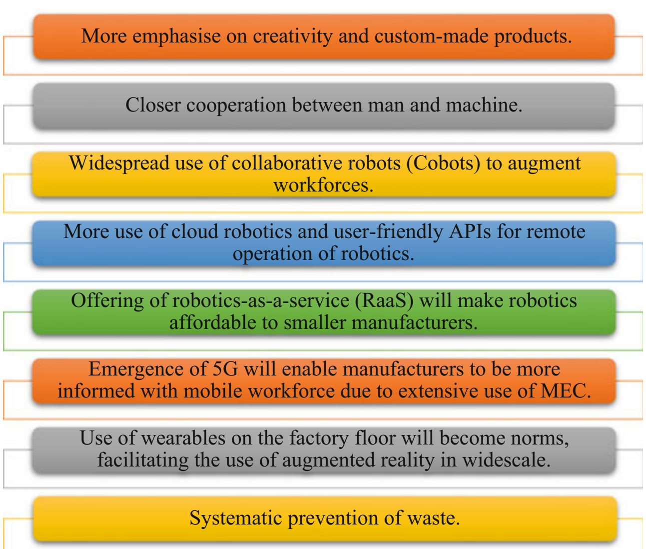


Fig. 19 Highlights of Industry 5.0

8 Conclusions

The industrial revolution has shifted the focus from agriculture to industry. With the technological invention and innovative ideas, the industry operations and manufacturing process have become more sophisticated day-by-day. It started with the utilising the steam engines to run machines as Industry 1.0. Thereafter, the introduction of assembly lines (Industry 2.0) and computers and factory automation (Industry 3.0) has changed the manufacturing scenario altogether. At present, we are in the era of Industry 4.0 which is hailed as the age of cyber-physical systems that has taken manufacturing and associated industry processes to an unforeseen level with flexible production including manufacturing, supply chain, delivery, and maintenance. The key enabler for this is the ubiquitous technologies which have led to a new term ubiquitous manufacturing, which means the manufacturing process can be handled from anywhere and anytime. In this chapter, we have seen how ubiquitous manufacturing has changed the traditional production planning and scheduling and how it has helped in automated material handling and dynamic reconfiguration. The ubiquitous manufacturing has been well supported by technologies such as AI, machine learning, smart robotics, Big Data analytics, etc. All of these, in unison, have piloted to smart automation. Advancements in ubiquitous technologies such as IoT, cloud and edge computing, real-time communications and many others have allowed industries to leverage ubiquitous manufacturing to its fullest. In the chapter, we have understood different similar and/or related manufacturing paradigms to ubiquitous manufacturing are also getting popular in different perspectives. Cloud manufacturing, cloud robotics, internet manufacturing, lean manufacturing, additive manufacturing, etc. to name a few. Although Industry 4.0 is yet to develop to its absolute and the industries are still in the transition state of adopting this, due to the rapid technological advancements, we are in the verge of entering to the era of Industry 5.0. Industry 5.0 is going to be all about collaboration between men and machines with more focus on customised manufacturing. It is expected that Industry 4.0 is surely going to be replaced by Industry 5.0 very soon.

References

1. R. E. Crandall, "Industry 1.0 to 4.0: the Evolution of Smart Factories," APICS, October 2017. [Online]. Available: http://www.apics.org/apics-for-individuals/apics-magazine-home/magazine-detail-page/2017/09/20/industry-1.0-to-4.0-the-evolution-of-smart-factories. [Accessed 7 April 2019].

2. E. Howard, "The Evolution of the Industrial Ages: Industry 1.0 to 4.0," 5 September 2018. [Online]. Available: https://www.simio.com/blog/2018/09/05/evolution-industrial-ages-industry-1-0-4-0/. [Accessed 7 April 2019].
3. M. Aggarwal, "History of The Industrial Revolution," [Online]. Available: http://www.historydiscussion.net/history/industrial-revolution/history-of-the-industrial-revolution/1784. [Accessed 7 May 2019].
4. Henry Ford in collaboration with Samuel Crowther, My Life and Work, Garden City, N.Y.: Page & Company, 1922.
5. C. Adams, The Sexual Politics of Meat, New York: Continuum, 1991.
6. G. D. Putnik and L. Wang, "Ubiquitous and cloud enterprise for manufacturing," *International Journal of Computer Integrated Manufacturing,* vol. 30, no. 4–5, p. 344–346, 2017.
7. ICS & Cybersecurity, "The 4 industrial revolutions," Sentryo, 23 February 2017. [Online]. Available: https://www.sentryo.net/the-4-industrial-revolutions/. [Accessed 7 April 2019].
8. P. Nissen, "Factory Automation from Industry 1.0 to Industry 4.0," 2016. [Online]. Available: https://www.qubiqa.com/Qubiqa-EN/Blog/Per-Nissen-gives-a-quick-overview-of-factory-automation-from-Industry-1.0-to-Industry-4.0-%E2%80%93-and-the-future-of-automation. [Accessed 7 April 2019].
9. S. V. Ticaret, "A Brief History of Industry," Bosch, 2017. [Online]. Available: http://www.sanayidegelecek.com/en/sanayi-4-0/tarihsel-gelisim/. [Accessed 7 April 2019].
10. J. Sheth, "The Industrial Revolution – From Industry 1.0 to Industry 5.0!," Supply Chain Game Changer™, 24 March 2019. [Online]. Available: https://supplychaingamechanger.com/the-industrial-revolution-from-industry-1-0-to-industry-5-0/. [Accessed 7 April 2019].
11. A. Sanders, C. Elangeswaran and J. Wulfsberg, "Industry 4.0 Implies Lean Manufacturing: Research Activities in Industry 4.0 Function as Enablers for Lean Manufacturing," *J. Ind. Eng. Manag.,* vol. 9, no. 3, 2016.
12. P. K. D. Pramanik, S. Pal and P. Choudhury, "Smartphone Crowd Computing: A Rational Solution towards Minimising the Environmental Externalities of the Growing Computing Demands," in *Emerging Trends in Disruptive Technology Management*, R. Das, M. Banerjee and S. De, Eds., CRC Press, 2019.
13. P. K. D. Pramanik, S. Pal and P. Choudhury, "Green and Sustainable High-Performance Computing with Smartphone Crowd Computing: Benefits, Enablers, and Challenges," *Scalable Computing: Practice and Experience,* vol. 20, no. 2, pp. 259-283, 2019.
14. P. K. D. Pramanik, B. Mukherjee, S. Pal, T. Pal and S. P. Singh, "Green Smart Building: Requisites, Architecture, Challenges, and Use Cases," in *Green Building Management and Smart Automation*, A. Solanki and A. Nayyar, Eds., IGI Global, 2019.
15. AB&R, "RFID," AB&R, 2019. [Online]. Available: https://www.abr.com/what-is-rfid-how-does-rfid-work/. [Accessed 11 May 2019].
16. Thomas, "Complete Guide to Actuators (Types, Attributes, Applications and Suppliers)," Thomas, 2019. [Online]. Available: https://www.thomasnet.com/articles/pumps-valves-accessories/types-of-actuators. [Accessed 11 May 2019].
17. Solanki, A., & Nayyar, A. (2019). Green Internet of Things (G-IoT): ICT Technologies, Principles, Applications, Projects, and Challenges. In *Handbook of Research on Big Data and the IoT* (pp. 379-405). IGI Global.
18. Batth, R. S., Nayyar, A., & Nagpal, A. (2018, August). Internet of Robotic Things: Driving Intelligent Robotics of Future-Concept, Architecture, Applications and Technologies. In *2018 4th International Conference on Computing Sciences (ICCS)*(pp. 151-160). IEEE.
19. Nayyar, A., Puri, V., & Le, D. N. (2017). Internet of nano things (IoNT): Next evolutionary step in nanotechnology. *Nanoscience and Nanotechnology*, *7*(1), 4-8.
20. P. K. D. Pramanik, S. Pal, A. Brahmachari and P. Choudhury, "Processing IoT Data: From Cloud to Fog. It's Time to be Down-to-Earth," in *Applications of Security, Mobile, Analytic and Cloud (SMAC) Technologies for Effective Information Processing and Management*, P. Karthikeyan and M. Thangavel, Eds., IGI Global, 2018, pp. 124-148.
21. Kaur, A., Gupta, P., Singh, M., & Nayyar, A. (2019). Data Placement in Era of Cloud Computing: a Survey, Taxonomy and Open Research Issues. *Scalable Computing: Practice and Experience*, *20* (2), 377-398.
22. Microsoft, "What is cloud computing?," Microsoft, 2019. [Online]. Available: https://azure.microsoft.com/en-in/overview/what-is-cloud-computing/. [Accessed 11 May 2019].
23. Singh, P., Gupta, P., Jyoti, K., & Nayyar, A. (2019). Research on Auto-Scaling of Web Applications in Cloud: Survey, Trends and Future Directions. *Scalable Computing: Practice and Experience*, *20*(2), 399-432.
24. Singh, S. P., Nayyar, A., Kaur, H., & Singla, A. (2019). Dynamic Task Scheduling using Balanced VM Allocation Policy for Fog Computing Platforms. *Scalable Computing: Practice and Experience*, *20*(2), 433-456.
25. P. K. D. Pramanik and P. Choudhury, "IoT Data Processing: The Different Archetypes and their Security & Privacy Assessments," in *Internet of Things (IoT) Security: Fundamentals, Techniques and Applications*, S. K. Shandilya, S. A. Chun, S. Shandilya and E. Weippl, Eds., River Publishers, 2018, pp. 37-54.
26. Singh, S. P., Nayyar, A., Kumar, R., & Sharma, A. (2019). Fog computing: from architecture to edge computing and big data processing. *The Journal of Supercomputing*, *75*(4), 2070-2105.
27. P. K. D. Pramanik, B. Upadhyaya, S. Pal and T. Pal, "Internet of Things, Smart Sensors, and Pervasive Systems: Enabling the Connected and Pervasive Health Care," in *Healthcare Data Analytics and Management*, N. Dey, A. Ashour, S. J. Fong and C. Bhatt, Eds., Academic Press, 2018, pp. 1-58.
28. P. K. D. Pramanik, S. Pal and M. Mukhopadhyay, "Healthcare Big Data: A Comprehensive Overview," in *Intelligent Systems for Healthcare Management and Delivery*, N. Bouchemal, Ed., IGI Global, 2018, pp. 72-100.
29. M. Rouse, "big data analytics," TechTarget, September 2018. [Online]. Available: https://searchbusinessanalytics.techtarget.com/definition/big-data-analytics. [Accessed 11 May 2019].
30. Qubole, "Overview of Big Data Analytics," Qubole, 2019. [Online]. Available: https://www.qubole.com/big-data-analytics/. [Accessed 11 May 2019].
31. Nayyar, A., & Puri, V. (2017). Comprehensive Analysis & Performance Comparison of Clustering Algorithms for Big Data. *Review of Computer Engineering Research*, *4*(2), 54-80.
32. B. Marr, "What Is The Difference Between Artificial Intelligence And Machine Learning?," Forbes, 6 December 2016. [Online]. Available: https://www.forbes.com/sites/bernardmarr/2016/12/06/what-is-the-difference-between-artificial-intelligence-and-machine-learning/#69fecbef2742. [Accessed 11 May 2019].
33. P. K. D. Pramanik, S. Pal and P. Choudhury, "Beyond Automation: The Cognitive IoT. Artificial Intelligence Brings Sense to the Internet of Things," in *Cognitive Computing for Big Data Systems Over IoT: Frameworks, Tools and Application*, A. K. Sangaiah, A. Thangavelu and V. M. Sundaram, Eds., Springer, 2018, pp. 1-37.
34. M. Rouse, "Cognitive computing," TechTarget, July 2018. [Online]. Available: https://searchenterpriseai.techtarget.com/definition/cognitive-computing. [Accessed 11 May 2019].
35. Reality Technologies, "The Ultimate Guide to Understanding Augmented Reality (AR) Technology," Reality Technologies, 2019. [Online]. Available: https://www.realitytechnologies.com/augmented-reality/. [Accessed 11 May 2019].
36. GE, "What is Additive Manufacturing?," GE, 2019. [Online]. Available: https://www.ge.com/additive/additive-manufacturing. [Accessed 11 May 2019].

37. EOS GmbH, "Additive Manufacturing, Laser-Sintering and industrial 3D printing - Benefits and Functional Principle," EOS GmbH, May 2018. [Online]. Available: https://www.eos.info/additive_manufacturing/for_technology_interested. [Accessed 11 May 2019].
38. SPI lasers, "Additive Manufacturing – a definition," SPI lasers, 2019. [Online]. Available: https://www.spilasers.com/application-additive-manufacturing/additive-manufacturing-a-definition/. [Accessed 11 May 2019].
39. M. Weiser, "Hot topics-ubiquitous computing," *Computer,* vol. 26, no. 10, pp. 71-72, 1993.
40. M. Rouse, "IoT analytics guide: Understanding Internet of Things data," TechTarget, November 2016. [Online]. Available: https://internetofthingsagenda.techtarget.com/definition/pervasive-computing-ubiquitous-computing. [Accessed 07 May 2019].
41. P. Peiris, "How IoT Strengthens Ubiquitous Computing," 25 May 2017. [Online]. Available: https://dzone.com/articles/how-iot-strengthens-ubiquitous-computing. [Accessed 30 November 2018].
42. G. Banavar and A. Bernstein, "Software infrastructure and design challenges for ubiquitous computing applications," *Communications of the ACM,* vol. 45, no. 12, pp. 92-96, 2002.
43. R. Want, "An Introduction to Ubiquitous Computing," in *Ubiquitous Computing Fundamentals*, J. Krumm, Ed., Boca Raton, Florida: CRC Press, 2010, pp. 1-36.
44. J. L. V. Barbosa, "Ubiquitous computing: Applications and research opportunities," in *IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)*, Madurai, 2015.
45. K. R. Prasanna and M. Hemalatha, "RFID GPS and GSM based logistics vehicle load balancing and tracking," *Procedia Engineering,* vol. 30, pp. 726-729, 2012.
46. T. Chen and H.-R. Tsai, "Ubiquitous manufacturing: Current practices, challenges, and opportunities," *Robotics and Computer-Integrated Manufacturing,* vol. 45, pp. 126-132, 2017.
47. X. Wang, S. K. Ong and A. Y. C. Nee, "A comprehensive survey of ubiquitous manufacturing research," *International Journal of Production Research,* vol. 56, no. 1-2, pp. 604-628, 2017.
48. Nayyar, A. (2011). INTEROPERABILITY OF CLOUD COMPUTING WITH WEB SERVICES. *International Journal of ElectroComputational World & Knowledge Interface*, *1*(1).
49. Nayyar, A. (2011). Private Virtual Infrastructure (PVI) Model for Cloud Computing. *International Journal of Software Engineering Research and Practices*, *1*(1), 10-14.
50. IBM Corporation, "Industrie 4.0 & Cognitive Manufacturing - Architecture Patterns, Use Cases & IBM Solution," 28 September 2018. [Online]. Available: https://www.ibm.com/downloads/cas/YKEDY8RD. [Accessed 2019 April 12].
51. J. Barcus, "5 Benefits of Shifting to Smart Manufacturing," Oracle, 29 March 2018. [Online]. Available: https://blogs.oracle.com/5-benefits-of-shifting-to-smart-manufacturing. [Accessed 07 May 2019].
52. C. Beebe, "The Benefits of Smart Manufacturing," Fishman, 2019. [Online]. Available: https://www.fishmancorp.com/benefits-smart-manufacturing/. [Accessed 07 May 2019].
53. Infinite Uptime, "Smart Factory and Its benefits on manufacturing industry," Infinite Uptime, 21 August 2018. [Online]. Available: https://infinite-uptime.com/blog/smart-factory-benefits-manufacturing/. [Accessed 07 May 2019].
54. W. Pao, "Smart manufacturing technology and how it benefits factories," asmag.com, 02 10 2018. [Online]. Available: https://www.asmag.com/showpost/26303.aspx. [Accessed 07 May 2019].
55. Fathym, "5 powerful benifits of IoT for the manufacturing industry," Fathym, 2018. [Online]. Available: https://fathym.com/2017/05/5-powerful-benefits-iot-manufacturing-industry/. [Accessed 07 May 2019].
56. MSRCosmos, "Challenges of the Manufacturing Industry, & Big Data Analytics," 22 August 2017. [Online]. Available: https://www.msrcosmos.com/blog/challenges-of-the-manufacturing-industry-big-data-analytics/. [Accessed 07 May 2019].
57. TCS, "Big Data Study," TCS, 2019. [Online]. Available: https://sites.tcs.com/big-data-study/manufacturing-big-data-benefits-challenges/. [Accessed 07 May 2019].
58. Big Data Value Association, "Big Data challenges in smart manufacturing," BDVA, Bruxelles, 2018.
59. S. Wang, D. L. Jiafu Wan and C. Zhang, "Implementing Smart Factory of Industrie 4.0: An Outlook," *International Journal of Distributed Sensor Networks,* 2016.
60. Q. Dai, R. Zhong, G. Q. Huang, T. Qub, T. Zhang and T. Y. Luo, "Radio frequency identification-enabled real-time manufacturing execution system: a case study in an automotive part manufacturer," *International Journal of Computer Integrated Manufacturing,* vol. 25, no. 1, pp. 51-65, 2012.
61. H. Luo, K. Wang, X. T. R. Kong, S. P. Lu and T. Qu, "Synchronised Production and Logistics via Ubiquitous Computing Technology," *Robotics and Computer Integrated Manufacturing,* vol. 45, pp. 99-115, 2017.
62. A. I. Corréa, A. Langevin and L.-M. Rousseau, "Scheduling and routing of automated guided vehicles: A hybrid approach," *Computers & Operations Research,* vol. 34, no. 6, pp. 1688-1707, 2007.
63. R. Y. Zhong, G. Q. Huang, S. Lan, Q. Dai, T. Zhang and C. Xu, "A two-level advanced production planning and scheduling model for RFID-enabled ubiquitous manufacturing," *Advanced Engineering Informatics,* pp. 799-812, 2015.
64. Siemens, "Pictures of the Future," 1996-2019. [Online]. Available: https://www.siemens.com/innovation/en/home/pictures-of-the-future/industry-and-automation/digitale-fabrik-rfid-in-industry.html. [Accessed 11 April 2019].
65. Identec Solutions, "Visibility of complex manufacturing and logistics operations delivers the fourth industrial revolution," [Online]. Available: https://www.identecsolutions.com/industry-4-0/#identec-tab-feature-1. [Accessed 9 May 2019].
66. C. Lam and W. Ip, "An Integrated Logistics Routing and Scheduling Network Model with RFID-GPS Data for Supply Chain Management," *Wireless Personal Communications,* vol. 105, no. 3, pp. 803-817, 2019.
67. E. Arica and D. J. Powell, "A framework for ICT-enabled real-time production planning and control," *Advances in Manufacturing,* vol. 2, no. 2, pp. 158-164, 2014.
68. J. Gubbi, R. Buyya, S. Marusic and M. Palaniswami, "Internet of Things (IoT): A vision, architectural elements, and future directions," *Future Generation Computer Systems,* vol. 29, no. 7, pp. 1645-1660, 2013.
69. Germany Trade & Invest (GTAI), "Industrie 4.0," Germany Trade & Invest (GTAI), 2019. [Online]. Available: https://www.gtai.de/GTAI/Navigation/EN/Invest/Industries/Industrie-4-0/Industrie-4-0/industrie-4-0-what-is-it.html. [Accessed 5 April 2019].
70. The European Factories of the Future Research Association (EFFRA), "Factories of the Future," The European Factories of the Future Research Association (EFFRA), 2019. [Online]. Available: https://www.effra.eu/factories-future. [Accessed 2 April 2019].
71. Center For Strategic & International Studies (CSIS), "Made in China 2025," June 2015. [Online]. Available: https://www.csis.org/analysis/made-china-2025. [Accessed 10 April 2019].
72. C. Yang, W. Shen and X. Wang, "The Internet of Things in Manufacturing Key Issues and Potential Applications," *IEEE Systems, Man, & Cybernetics Magazine,* vol. 4, no. 1, pp. 6-15, 2018.
73. P. K. D. Pramanik, S. Pal, G. Pareek, S. Dutta and P. Choudhury, "Crowd Computing: The Computing Revolution," in *Crowdsourcing and Knowledge Management in Contemporary Business Environments*, R. Lenart-Gansiniec, Ed., IGI Global, 2018, pp. 166-198.

74. Q. Qi and F. Tao, "Digital Twin and Big Data Towards Smart Manufacturing and Industry 4.0: 360 Degree Comparison," *IEEE ACCESS,* vol. 6, pp. 3585-3593, 2018.
75. P. Leitaˇo, A. W. Colombo and S. Karnouskos, "Industrial automation based on cyber-physical systems technologies:Prototype implementations and challenges," *Computers in Industry,* vol. 81, pp. 11-25, 2016.
76. Guardian News & Media Limited, "Google Glass – hands-on review," 2019. [Online]. Available: https://www.theguardian.com/technology/2013/jul/02/google-glass-review-augmented-reality. [Accessed 1 May 2019].
77. J. Lee, B. Bagheri and H.-A. Kao, "A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems," *Manufacturing Letters,* vol. 3, pp. 18-23, 2015.
78. K. Schwab, The Fourth Industrial Revolution, Penguin UK, 2017.
79. H. Kagermann, "Change Through Digitization—Value Creation in the Age of Industry 4.0," in *Management of Permanent Change*, Springer Gabler, Wiesbaden, 2015, pp. 23-45.
80. ABB Group, "ABB unveils the future of human-robot collaboration: YuMi®," 9 September 2014. [Online]. Available: https://new.abb.com/news/detail/13110/abb-unveils-the-future-of-human-robot-collaboration-yumir. [Accessed 21 April 2019].
81. Karen Lewis, "Adaptive robots with Watson IoT and KUKA," IBM, 2 May 2017. [Online]. Available: https://www.ibm.com/blogs/internet-of-things/adaptive-robots-watson-kuka/. [Accessed 22 April 2019].
82. N.-A. David, H. M. Yip, Z. Wang, Y.-H. Liu, F. Zhong, T. Zhang and P. Li, "Automatic 3-D Manipulation of Soft Objects by Robotic Arms With an Adaptive Deformation Model," *IEEE Transactions on Robotics,* vol. 32, no. 2, pp. 429-441, 2016.
83. pi4, "Machine Vision and robotics - a brilliant combination pi4 has the expertise in both areas," [Online]. Available: https://www.pi4.de/english/systems/workerbot/workerbot4tm.html.
84. D. Wu, J. L. Thames, D. W. Rosen and D. Schaefer, "Enhancing the Product Realization Process With Cloud-Based Design and Manufacturing Systems," *Journal of Computing and Information Science in Engineering,* vol. 13, no. 4, 2013.
85. S. Wang, J. Wan, D. Li and C. Zhang, "Implementing Smart Factory of Industrie 4.0: An Outlook," *International Journal of Distributed Sensor Networks,* vol. 12, no. 1, 2016.
86. Xu and Xun, "From cloud computing to cloud manufacturing," *Robotics and Computer-Integrated Manufacturing,* vol. 28, no. 1, pp. 75-86, 2012.
87. J. Queiroz, P. Leitão and E. Oliveira, "Industrial Cyber Physical Systems Supported by Distributed Advanced Data Analytics," in *International Workshop on Service Orientation in Holonic and Multi-Agent Manufacturing (SOHOMA 2016)*, 2017.
88. S. Raileanu, T. Borangiu, O. Morariu and I. Iacob, "Edge Computing in Industrial IoT Framework for Cloud-based Manufacturing Control," in *22nd International Conference on System Theory, Control and Computing (ICSTCC)*, 2018.
89. Puri, V., Nayyar, A., & Raja, L. (2017). Agriculture drones: A modern breakthrough in precision agriculture. *Journal of Statistics and Management Systems*, *20*(4), 507-518.
90. Q. Qi, D. Zhao, T. W. Liao and F. Tao, "Modeling of cyber-physical systems and digital twin based on edge computing, fog computing and cloud computing towards smart manufacturing," in *13th International Manufacturing Science and Engineering Conference*, 2018.
91. C. Byers, "Fog computing for industrial automation," CISCO, 8 March 2018. [Online]. Available: https://www.controleng.com/articles/fog-computing-for-industrial-automation/. [Accessed 1 April 2019].
92. P. K. D. Pramanik, A. Nayyar and G. Pareek, "WBAN: Driving E-Healthcare Beyond Telemedicine to Remote Health Monitoring. Architecture and Protocols," in *Telemedicine Technologies: Big data, Deep Learning, Robotics, Mobile and Remote Applications for Global Healthcare*, D. J. Hemanth and V. E. Balas, Eds., Elsevier, 2019, pp. 89-119.
93. C.-C. Lin, D.-J. Deng, Z.-Y. Chen and K.-C. Chen, "Key Design of Driving Industry 4.0: Joint Energy-Efficient Deployment and Scheduling in Group-Based Industrial Wireless Sensor Networks," *Recent Advances in Green Industrial Networking,* vol. 54, no. 10, pp. 46-52, 2016.
94. M. Yi-Wei, C. Yung-Chiao and C. Jiann-Liang, "SDN-Enabled Network Virtualization for Industry 4.0 Based on IoTs and Cloud Computing," in *19th International Conference on Advanced Communication Technology (ICACT)*, Bongpyeong, South Korea, 2017.
95. Reis, J. Zonichenn, Gonçalves and R. Franco, "The Role of Internet of Services (IoS) on Industry 4.0 Through the Service Oriented Architecture (SOA)," in *Advances in Production Management Systems. Smart Manufacturing for Industry 4.0. APMS*, 2018.
96. J. Jung, B. Song, K. Watson and T. Usländer, "Design of Smart Factory Web Services Based on the Industrial Internet of Things," in *50th Hawaii International Conference on System Sciences*, 2017.
97. Amazon, "Manufacturing: Optimize production, speed time to market, and deliver innovative products and services with AWS Cloud," Amazon, 2019. [Online]. Available: https://aws.amazon.com/manufacturing/. [Accessed 25 March 2019].
98. Deloitte, "Industry 4.0 and the digital twin Manufacturing meets its match," Deloitte, May 2017. [Online]. Available: https://www2.deloitte.com/insights/us/en/focus/industry-4-0/digital-twin-technology-smart-factory.html. [Accessed 30 March 2019].
99. Oracle, "Digital Twins for IoT Applications A Comprehensive Approach to Implementing IoT Digital Twins," *Oracle White Paper,* pp. 1-9, January 2017.
100. Datacore Software, "Storage Virtualization," Datacore Software, 2019. [Online]. Available: https://www.datacore.com/storage-virtualization/. [Accessed 12 April 2019].
101. H. Enming, F. Bingyan, L. Chenhan, Y. Jianzhong and C. Jihong, "A design of CNC architecture based on cloud computing," *Journal of Engineering Manufacture,* vol. 233, no. 4, pp. 1260-1268, 2018.
102. D. Mourtzis, N. Milas and N. Athinaios, "Towards Machine Shop 4.0: A General Machine Model for CNC machine-tools through OPC-UA," in *6th CIRP Global Web Conference "Envisaging the future manufacturing,design, technologies and systems in innovation era*", 2018.
103. Gardner Business Media, Inc., "CNC Intro-The Key Concepts Of Computer Numerical Control," May 2018. [Online]. Available: https://www.mmsonline.com/articles/cnc-intro-the-key-concepts-of-computer-numerical-control. [Accessed 31 March 2019].
104. HNC Electric, "Global Service," 2014. [Online]. Available: http://www.hncelectric.com/en_download.aspx?cid=36&category_id=0. [Accessed 1 May 2019].
105. FANUC, "FANUC CNC," February 2015. [Online]. Available: https://www.fanuc.eu/il/en/cnc. [Accessed 11 April 2019].
106. Siemens, "Premium class CNCs – delivering ultimate performance," Siemens, 2019. [Online]. Available: https://new.siemens.com/global/en/products/automation/systems/cnc-sinumerik/automation-systems/sinumerik-840.html. [Accessed 1 April 2019].
107. S. Lemaignan, A. Siadat, J.-Y. Dantan and A. Semenenko, "MASON: A Proposal For An Ontology Of Manufacturing Domain," in *IEEE Workshop on Distributed Intelligent Systems: Collective Intelligence and Its Applications (DIS'06)*, Prague, Czech Republic, 2006.
108. P. Leitao, A. Colombo and F. Restivo, "ADACOR: A Collaborative Production Automation and Control Architecture," *IEEE Intelligent Systems,* pp. 58-66, 2005.
109. I. Horrocks, P. F. Patel-Schneider, H. Boley, S. Tabet, B. Grosof and M. Dean, "SWRL: A Semantic Web Rule Language Combining OWL and RuleML," 21 May 2004. [Online]. Available: https://www.w3.org/Submission/SWRL/.

110. H. Knublauch, "SPIN - Modeling Vocabulary," 22 February 2011. [Online]. Available: https://www.w3.org/Submission/spin-modeling/.
111. E. Järvenpää, N. Siltala, O. Hylli and M. Lanz, "The development of an ontology for describing the capabilities of manufacturing resources," *Journal of Intelligent Manufacturing,* pp. 959-978, 2019.
112. L. Zhang, Y. Luo, F. Tao, B. H. Li, L. Ren, X. Zhang, H. Guo, Y. Cheng, A. Hu and Y. Liu, "Cloud manufacturing: A new manufacturing paradigm," *Enterprise Information Systems,* vol. 8, no. 2, pp. 167-187, 2012.
113. X. Xu, "From cloud computing to cloud manufacturing," *Robotics and Computer-Integrated Manufacturing,* vol. 28, no. 1, pp. 75-86, 2012.
114. D. Wu, M. J. Greer, D. W. Rosen and D. Schaefer, "Cloud manufacturing: Strategic vision and state-of-the-art," *Journal of Manufacturing Systems,* vol. 32, no. 4, pp. 564-579, 2013.
115. G. Hu, W. Tay and Y. Wen, "Cloud robotics: Architecture, challenges and applications," *IEEE Network,* vol. 26, no. 3, pp. 21-28, 2012.
116. J. Wan, S. Tang, H. Yan, D. Li, S. Wang and A. V. Vasilakos, "Cloud robotics: Current status and open issues," *IEEE Access,* vol. 4, pp. 2797-2807, 2016.
117. Y. Fan, D. Zhao, L. Zhang, S. Huang and B. Liu, "Manufacturing grid: Needs, concept and architecture," *Lect. Notes Comput. Sci.,* vol. 3032, pp. 653-656, 2004.
118. M. R¨ußmann, M. Lorenz, P. Gerbert, M. Waldner, J. Justus, P. Engel and M. Harnisch, "Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries," Boston Consulting Group, 2015.
119. J. Lee, B. Bagheri and C. Jin, "Introduction to cyber manufacturing," *Manufacturing Letters,* vol. 8, pp. 11-15, 2016.
120. P. Pontrandolfo and O. G. Okogbaa, "Global manufacturing: a review and a framework for planning in a global corporation," *International Journal of Produc-tion Economics,* vol. 37, no. 1, pp. 1-19, 1999.
121. J. X. Jiao, X. You and A. Kumar, "An agent-based framework for collaborative negotiation in the global manufacturing supply chain network," *Robotics and Computer-Integrated Manufacturing,* vol. 22, no. 3, pp. 239-255, 2006.
122. C. Lee, C. S. Leem and I. Hwang, "PDM and ERP information methodolo-gy using digital manufacturing to support global manufacturing," *International Journal of Advanced Manufacturing Technology,* vol. 53, no. 1-4, pp. 399-409, 2011.
123. V. G. Bharath and R. Pati, "Virtual Manufacturing: A Review," *International Journal of Engineering Research & Technology,* pp. 355-364, 2015.
124. K. Kumar, D. Zindani and J. P. Davim, "Introduction to Virtual Manufacturing," in *Advanced Machining and Manufacturing Processes. Materials Forming, Machining and Tribology*, Springer, Cham, 2018.
125. M. Olender and D. Krenczyk, "Practical application of game theory based production flow planning method in virtual manufacturing networks," *IOP Conference Series: Materials Science and Engineering,* vol. 145, no. 022031, 2016.
126. R. Shah and P. T. Ward, "Defining and developing measures of lean production," *Journal of operations management,* vol. 25, no. 4, pp. 785-805, 2007.
127. A. Gunasekaran, Y. Y. Yusuf, E. O. Adeleye, T. Papadopoulos, D. Kovvuri and D. G. Geyi, "Agile manufacturing: an evolutionary review of practices," *International Journal of Production Research,* pp. 1-21, 2018.
128. V. Manivelmuralidaran, "Agile Manufacturing – An overview," *International Journal of Science and Engineering Applications,* vol. 4, no. 3, pp. 156-159, 2015.
129. S. Vaidya, P. Ambad and S. Bhosle, "Industry 4.0 - Glimpse," *Procedia Manufacturing,* vol. 20, p. 233–238, 2018.
130. W. Gao, Y. Zhang, D. Ramanujan, K. Ramania, Y. Chen, C. B. Williams, C. C. L. Wang, Y. C. Shin, S. Zhang and P. D. Zavattieri, "The status, challenges, and future of additive manufacturing in engineering," *Computer-Aided Design,* vol. 69, pp. 65-89, 2015.
131. U. M. Dilberoglu, B. Gharehpapagh, U. Yaman and M. Dolen, "The role of additive manufacturing in the era of industry 4.0.," *Procedia Manufacturing,* vol. 11, pp. 545-554, 2017.
132. F. v. Eijnatten, G. D. Putnik and A. Sluga, "Chaordic Systems Thinking for Novelty in Contemporary Manufacturing," *CIRP Annals - Manufacturing Technology,* vol. 56, no. 1, pp. 447-450, 2007.
133. F. v. Eijnatten, "Chaos and Complexity: An Overview of the 'New Science' in Organization and Management," *La Revue des Sciences de Gestion,* vol. 40, pp. 123-165, 2004.
134. A. Hobbs, "Complete guide: 10 smart factory trends to watch in 2019," 12 December 2018. [Online]. Available: https://internetofbusiness.com/complete-guide-10-smart-factory-trends-to-watch-in-2019/. [Accessed 7 May 2019].
135. P. Waterfield, "Fine watches, craft beer and the psychology of Industry 5.0," 27 April 2018. [Online]. Available: https://enterpriseiotinsights.com/20180427/channels/fundamentals/the-psychology-of-industry-50-tag99. [Accessed 7 May 2019].

Pijush Kanti Dutta Pramanik is a PhD Research Scholar in the Department of Computer Science and Engineering at National Institute of Technology, Durgapur, India. He has acquired a range of professional qualifications in the core and allied fields of Computer Science and Information Technology, viz., MIT, MCA, MBA (IT), MTech (CSE), and MPhil (CS) and has more than 10 years of teaching experience in graduate and post-graduate levels. He has qualified UGC-NET in Computer Science and Applications as well as in Management. Pijush Kanti is actively engaged in research in the domains of IoT, Grid Computing, Fog Computing, Crowd Computing, Mobile Computing, and Recommendation Systems and has published more than 30 research articles in the refereed journals, edited books, and reputed international conferences. He can be reached at pijushjld@yahoo.co.in.

Bulbul Mukherjee is an Assistant Professor in the Department of Computer Science and Engineering at Bengal Institute of Technology, India. She has received MTech degree from MAKAUT, West Bengal, India and has several years of teaching experience. Her domains of research interest are Software Engineering, IoT, Cloud Computing, Machine Learning, etc.

Saurabh Pal is an Assistant Professor in the Department of Computer Science and Engineering and Information Technology at Bengal Institute of Technology, India. He has more than 10 years of teaching experience in the field of Computer Science. He holds a BSc from the University of Calcutta, India, MSc-IT from Allahabad Agricultural Institute, India, and MTech-IT from Jadavpur University, India. Presently he is pursuing PhD in Computer Science and Engineering from National Institute of Technology, Durgapur, India. His primary research area includes Education Technology, Mobile Computing, Context-aware Computing, Semantic Web, and Natural Language Processing. He has published his research in many refereed journals, edited books, and international conferences.

Bijoy Kumar Upadhyaya received BTech degree in Electronics and Communication Engineering from North Eastern Regional Institute of Science and Technology (NERIST), Itanagar, India in 1998, Masters in Electronics and Telecommunication Engineering and PhD (Engineering) from Jadavpur University, Kolkata, India in 2007 and 2017, respectively. He joined Tripura Institute of Technology (TIT, erstwhile known as Polytechnic Institute), Narsingarh, Tripura, India as a Lecturer in 2000. He is presently working as Associate Professor in the Department of Electronics and Communication Engineering at TIT. He is a member of IEEE, Institution of Electronics and Telecommunication Engineering (IETE), Indian Society for Technical Education (ISTE), and Fellow of Institution of Engineers (India). He has more than 20 publications in peer-reviewed journals, edited books, and international and national conferences. He has been the editor of two edited books. His research area is Error Control Coding and its application in digital communication and digital system design using Hardware Description Languages.

Shubhendu Dutta holds an engineering degree along with a postgraduate degree in Management. As a technology professional with over 23 years of experience in various industries, he has successfully led large size delivery and account management teams in organisations like IBM. He has also been an integral part of the telecom industry revolution in India and has led several transformation programs for several large telecom firms. In his recent stint as an Information Security consultant, he is a Cyber Security advisor to the world's one of the largest National Identity management program (Aadhaar) for the Government of India. As a technology evangelist and researcher, he also pursues his academic interests in Digitisation and Cyber Security domains. He is also a visiting faculty in some of the top management schools in India.

si^3-Industry: Cloud Computing in Industry 4.0

Bandana Mahapatra

Abstract

The name "Cloud computing" has been named after the fact of information's that are retrieved is generally found remotely either in the cloud or on a virtual space. Companies providing cloud services facilitates to the users, helping them to store files and applications at remote servers and thereafter accessing all data's through the Internet. This implies the flexibility for the user to be able to access the resources and allowing them to work remotely as per their convenience. The concept of Cloud computing takes away the heavy burden of lifting required in the procedure of crunching and processing data off the devices the user carries around or sit and work at. The technology also moves all of these work into huge computer clusters present far away in cyberspace. Here the Internet takes place of the cloud, where the data, work, and applications are accessible from any device which can be connected to the Internet, irrespective of the geographic location. Recently the concept of cloud computing has contributed towards causing a major shift in the IT industry. Various new technologies have evolved, introducing new methods to virtualize IT systems and to access the required applications over the Internet, through web-based applications removing the need of any IT related costs for both hardware and servers.

Keywords

Cloud technology for industry · Cloud infrastructure · Cloud in manufacturing · Cloud integration

1 Introduction

As we all know typically an IT environment building involves purchasing of servers, hardware's, licenses as well as installation of software. This process is considered as lengthy along with being expensive which brings along many infrastructural demands and long deployment cycles [1]. This complete IT based internal model can said to be a common place. But as we know IT sector is coming up with lot new technologies. Currently we can state that, utility based and service-oriented IT model is no more a plain mere hardware or software market. Recently the industries have offered various email apps, production systems security, option storage, as well as the backup services and many more or just a few of IT components which can be moved onto the cloud [2, 3].

This trend in the IT sectors and the software developers have influenced various industry where the industrial sectors are trying to incorporate and adjust to these recent innovations in order to benefit themselves. The various aspects of cloud in industrial sector can be seen in Fig. 1. Few variations caused in the industry due to the incorporation of cloud can be listed as follows [3, 4]:

1. **Traditional IT job skills are being revamped** as new skills and specialties are increasing. Prior to make a move to cloud, the IT staff is required to completely understand the benefits of the cloud computing as well as ways of integrating it to the current business model. Here security as well as the maintenance issues are required to be discussed at a priority basis with the cloud. Computing vendors along with the reputed IT department who would oversee the process of migration and ongoing relationship with the cloud providers [5].
2. **The IT infrastructure undergoes crucial changes**: With majority of applications being transferred to the cloud, i.e. public or a private cloud. Here the software developers

B. Mahapatra (✉)
School of Data Science, Symbiosis Skills and open University, Pune, Maharashtra, India

A. Nayyar, A. Kumar (eds.), *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-14544-6_6

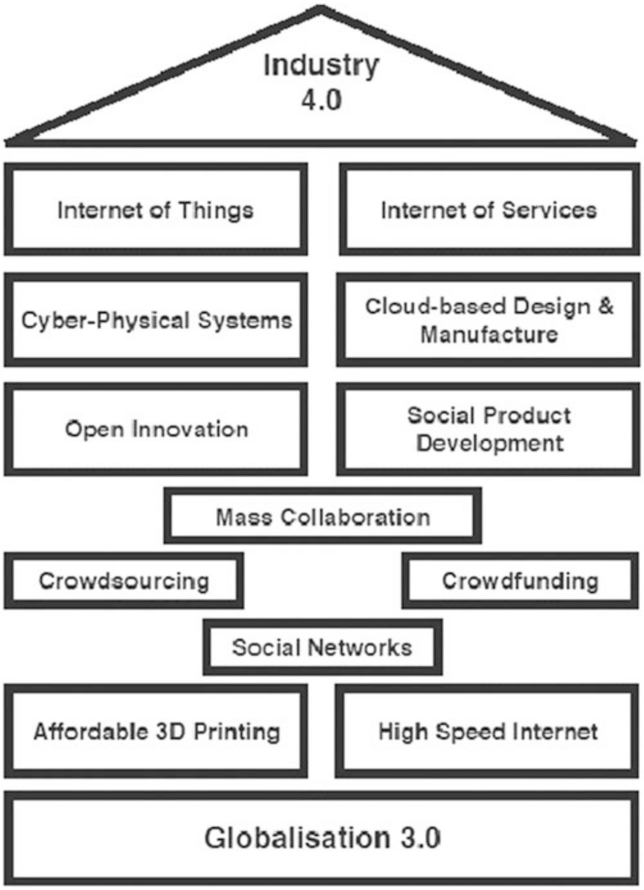


Fig. 1 Contribution of cloud computing in industry

are required to make an adjustment to the ways the applications are created as well as delivered.

3. **The number of employees required as a support**: Staff is reduced along with the reduction in desktop support. However, the need of training the employees to work with and understand the new system and application is added [6].
4. **The efforts needed in order to maintain the data is also diminished**: The relocation of data's and resources to the cloud front results in loss of physical control reasoning to its storage at the vendors data centre. The clients here undergo stress regarding security as well as accessibility aspects, hence making it all the more important to meet both the requirements.
5. **Security**: the cloud providing firms offering a managed cloud solution induct security experts as staff who manage the application as well as handle security related issues.
6. **Highly Customizable software**: Majority of the software's used by industry can be said as 'non cloud appropriate'. This issue is addressed by the software developers who intervene by creating cods specially designed for clouds. However, the cloud providers should also contribute in order to make the transition an easy process. Once applications are SaaS, the job of IT department trouble shooting reduces [7, 8].

Fig. 2 Contribution of cloud in retail industry

As appropriately defined, cloud computing is all about shifting the physical resources in order to increase both the efficiency as well as utility. Figure 2 shows the contribution of cloud computing in retail industry.

Incorporating cloud services also allows the companies to focus on other production activities rather than in IT process [9].

The chapter addresses the various contributions of the cloud computing in order to enhance as well as revolutionise the industry as a whole. In Sect. 2, cloud based infrastructure is presented, Sect. 4, is about independent as well as integrated modelling, Sect. 5, discusses sustainable governance with wide and affordable information access and finally the chapter is concluded in Sect. 6.

2 Cloud Based Infrastructure for Industry

The concept of cloud is no more new, but its contribution is still revolutionary evolving various technology in divergent fields. It has completely evolved the business computing and software architectures, converting the right set of services into iterative and scalable set of applications that has constantly transformed in order to meet out the requirements of companies as well as consumers [10].

In the current era of rapidly changing, hyper competitive landscape the business world is required to offer superior flexibility and speed to accomplish the operational success in the form of satisfaction to the customers demand following the solutions provided in spite of its non-scalability or incapable of delivering services at a required speed may be a cause of failure in business. This incompetency in performance at the business front may be due to lack of scalable technology in the hosted platforms which cause them to fail in performance while handling large number of subscribers leaving many of them in dark [10, 11]. As we know, the technology that cannot scale would ultimately crash and similar result can be expected for the customer base if they don't adapt and grace themselves with needed updates.

A fail in meeting this requirement can put the entire industry in a problematic state. The technology as of now is rapidly growing where the constant factor seen is change. The contribution of cloud technology in meeting the current marketing strategy, upcoming business requirements and operational challenges are [12]:

1. **The power to Transform**: the cloud platforms carry with them the resource to globally scale up as well as down, spontaneously as the demand fluctuates, making way for unlimited opportunities for the business as well as customers.
2. **Cost Reduction**: They assist in reduction of cost since business charges are made by cloud service provider when the customer makes use of their platform.
3. **Ease of Collaboration**: The cloud facilitates easy collaboration across various locations present in the global world that are marked by strict deadline and expanding the customers as well as employee bases where the move of the cloud is considered to be imperative for industry to dealt with [13, 14].

For start-ups as well as big and established industries the cloud concept have supported them to better manage any form of disruptions, reinvent the business models and have pumped up the massive improvement in the areas of delivery of appropriate services. For e.g., five years back Adobe noticed that a perpetual licensing model limited is quite capable to deliver new innovations and other capabilities with invention of new technology and launch of trendy and powerful devices like phones, browsers, mobile apps, the costumed based requirements are continuously revolutionising. In order to update itself to meet this requirement, adobe had to move from the traditional boxed software model to a subscription-based licensing management model which later on evolved as the adobe creative cloud [15, 16]. This shift on to the cloud gave a boost to both usage as well as flexibility, for customers as well as the adobe's business prospects. This transition brought about greater flexibility, scalability and more transparency into how users were managing licences.

Based on the recent 'Gartner Research Report', the concept of cloud computing has gained lot of popularity across huge number of industries for the basic business support functions. The research shows, cloud computing concept is being availed for much more than more IT functions. Many industries currently view cloud computing with the context of its support into succeeding in case of evolving market place.

2.1 Regulated Industries and Cloud Computing

The research shows the contribution of cloud computing is considered as vital in many kinds of industries like banking insurance etc. who use the cloud iterative in order to sere various competitive functions.

1. **Insurance**: In case of the insurance company the private clouds are preferred since they are more secured in comparison to the public cloud. However, it is predicted that, by 2015 the industry association with the community clouds would gain its popularity.
2. **Banking**: In case of the banking sectors, the major concern is regarding the security aspects of cloud environment. Hence the banking sectors make use of the clouds for administrative functions like e-mails, file sharing, as well as sharing of notes.
3. **Government**: Having multiple opportunities of being used in a variety of ways always exist in case of a cloud computing. But it is still not accepted though its biggest opportunity are in areas of cloud computing, reasoning the security issues related to it.

2.2 Unregulated Industry and Cloud Computing

The industries need both the private as well as public cloud in a far more ardent manner. Certain specific ways where the industry make use of the cloud computing are [19, 20]:

1. **Retail**: in the areas of retailing industry, clouds are mostly implemented as IaaS, or PaaS solutions. The aspects of security, availability, as well as vendor maturity are considered while deciding what functions they would like to deploy from cloud.
2. **Media**: the current era audience are able to access contents of all forms in a variety of ways. The service providers as well as application developers, both explore a vision based on cloud to enable multiscreen entertainment.
3. **Manufacturing**: the industry may make use of cloud for planning the logistics, functionalities for sales and support, Human Resource Management, Product

development process, as well as the life cycle management along with certain manufacturing operations.

The cloud computing has been adopted by variety of industries at varied levels due to the security causes, and certain other features needed by them [20].

3 Cloud Based Framework for Production

The futuristic vision of all the manufacturing environments is the ability to customize products easily at a low cost. In order to meet this requirement for customization of individual component/parts in a relatively easier manner CAD, CAM technologies have been used. Figure 3 shows the components of a MaaS environment [21].

1. **CAD**: Computer Aided Design is basically a computer technology which is about designing products along with documenting the entire designing process. CAD basically facilitates the process of manufacturing by transferring the diagrammatic data's of the products material process, tolerance and dimension considering the specific conventions for the product. The CAD is generally used for producing either 2-Dimensional or 3-Dimensional diagrams which may later on be rotated in order to behave viewed from any angle. Here a special printer or plotter is ideally needed for printing professional design [22].

   The CAD may also be termed as a Computer-Aided-Geometric Design (CAGD) when meant to design geometric shapes or Computer Aided design and Drafting (CADD) while performing designing and drafting nature of work.

   The CAD systems are basically used for majority of computer related platform such as Windows, Linux, Unix, Mac, OS. The whole idea of combining a CAD into a Cloud began in 2012, with the advent of auto desk with launch of fusion 360. Here the CAD users had a software option which offered few of the benefits of clouds like access mobility i.e. anywhere, platform agnosticism, comparatively preferable, collaboration convenience, high flexibility etc. [23, 24].

   The entire concept of moving onto the clouds is to improve the product quality as well as catering to the customer services which is definitely an important criterion met by industry via cloud [24].

   CADD is typically used for

   1. Production of detailed engineering related designs via 2D and 3D diagrams of the physical components of manufactured products.
   2. It can create conceptual design, product layout, strength and dynamic analysis of the assembling and the manufacturing process.
   3. To prepare reports regarding its environmental impact, where the computer aided designs are generally used in case of photographs for both producing as well as rendering of the appearance while new structures are being built [25].

2. **CAM:** The CAM or Computer Aided Manufacturing concept is about using software in order to take over the machine tools that are related once in the manufacturing process of the work pieces. CAM can also be defined as the usage of computer in order to help out operations of

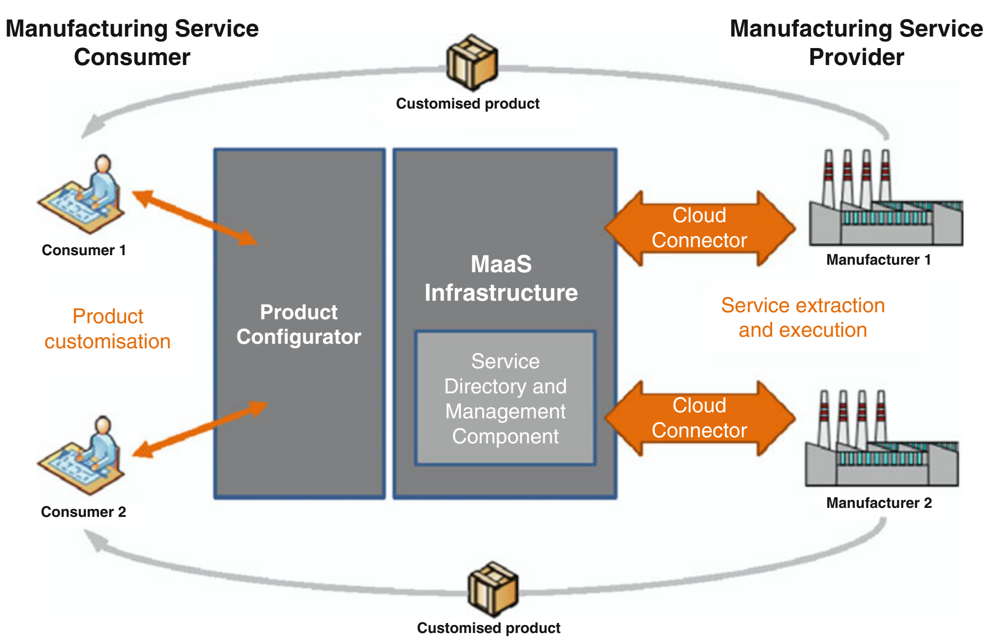


Fig. 3 Processing of manufacturing service descriptions in the MaaS environment

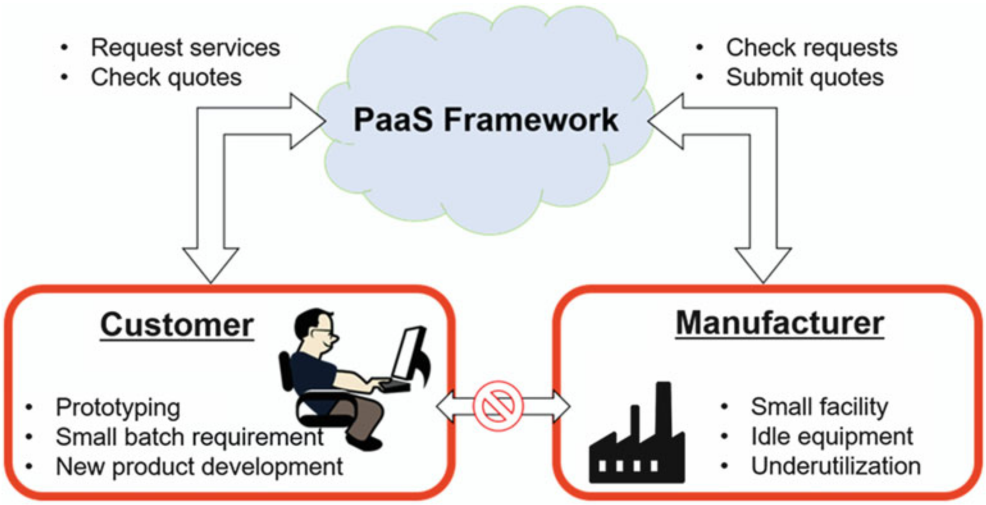


Fig. 4 Platform as a service framework

the manufacturing plants which include the procedure of planning, management, transportation and storage. Its main area is creation of a process that can enhance the production rate, components as well as tooling with more accuracy in dimensions along with material consistency. In majority of cases only required amount of raw materials are used, thereby minimizing the waste which in the other hand reduces the energy consumption [26].

Apart from this requirement there has been even greater need of producing bespoke devices as well as machine that could represent the assembling of many individual tailored components. Such kind of products generally need a supply chain that involves different manufacturers whose outputs are coordinated so as to extract the subcomponents that are needed to construct a given design. It has been vividly clear that creation of such a flexible production network requires a sophisticated IT infrastructure which can relate and map the customer specific product configuration to the specific process plants that are generally put to work in a flexible manufacturing network [27, 28]. This leads to a two-way exchange, which is needed between the suppliers manufacturing the capability which includes the functionality, cost and availability.

Here the customized products have a detailed description of the components parts that it needs in a language analogue with respect to the capability of individual suppliers. In case of an advanced manufacturing environment envisaged, no reason holds for allowing the designers in order to specify the size that are larger than that of production systems currently can possibly manufacture. As a result, it is required that the background limits of the manufacturing resources that are currently present for a product designer that are reflected in the design environment along with limiting the range of size should be considered for usage [29]. This possibility of the dynamic supply network for retail of consumer products that have been expressed by multiple online retailers.

The cloud computing framework is quite common being almost more than a decade old. It is defined by key features such as scalability, location transparency, etc. the main efforts are concentrated at realising the desire to demonstrate the cloud manufacturing environment that can transmit the key characteristics of cloud-based applications into the manufacturing paradigm [30]. Here the final resulting framework manufacturing as a service (MaaS) may be conceptually similar to paradigms like platform-as-a-service (PaaS) System as shown in Fig. 4, Software-as-a Service, or Infrastructure-as-a-Service, but involves unique variety of challenges that need new technology-based solutions to make it a reality.

3.1 Cloud Based Design and Manufacturing

The concept for cloud computing has proved itself as a disruptive technology during its internal application field in IT. It takes the benefits of existing technologies like utility computing, parallel computing, as well as virtualization [31]. Few of its main features includes, scalability, elasticity on demand computing, as well as self service provisioning [2]. It has been picked up from the original cloud computing paradigm and incorporated into the stream of computer aided product development process.

The concept of cloud based design and manufacturing as shown in Fig. 5 has gained major speed and attention from both the field of industry as well as academia. The CBDM concept is

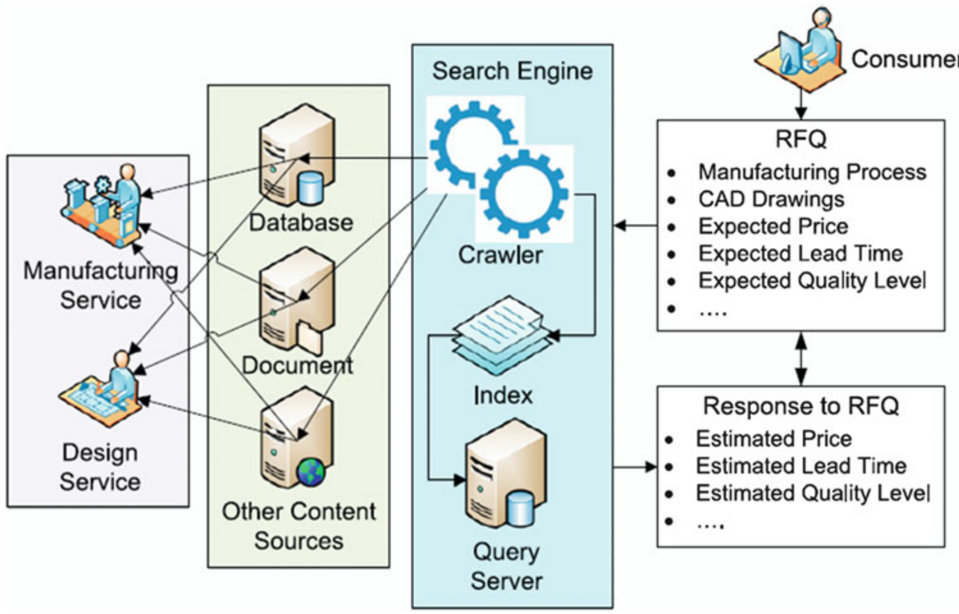


Fig. 5 Services provided by cloud to consumers in manufacturing and design sector of industry

all about a service oriented networked product development model where the consumers generally fail to configure, select, utilize customised product realization resources and services consisting all from CAE software to reconfigurable manufacturing system. The various paradigms of cloud manufacturing can be seen in Fig. 6. This task has been realised via the synergetic integration of the four key cloud computing services models i.e. IaaS, PaaS, HaaS, SaaS etc. [3, 31–33].

To completely understand the concepts like breadth, depth, along with the other opportunities of CBDM as an emerging paradigm for distributive as well as collaborative product development [25]. It is necessary to perform an indepth study, over Cloud Based Design (CBD), Cloud Based Manufacturing (CBM).

CBD: the concept of CBD indicates a networked design model which makes use of cloud computing, Service Oriented architecture (SOA), web 2.0 along with the semantic web technologies, in order to facilitate the cloud based engineering design services in a distributive as well as collaborative environment [7, 34]. Certain vital needs of a CBD system consists of

(a) It should be cloud computing based.
(b) It should be commonly available to all the mobile devices.
(c) It should be able to handle the complex information flow.

In case of absence of a proper CBD system, certain organizations have also tried into developing, providing as well as selecting the critical components for a CBD system e.g. autodesk offers a cloud based platform i.e. Autodesk 360 [17, 18, 35] that enables the users into converting the photos of the artifacts into 3D models, creating as well as editing the 3D models, generation of associated prototypes, with the remote 3D printers accessed via internet. In addition autodesk also offers a cloud based mobile application.

Fig. 6 Paradigms of cloud computing in manufacturing

AutoCAD 360 allows the design engineers into viewing, editing as well as sharing the auto CAD digital files while using the mobile devices e.g. smartphones or tablets e.g. 100kgarages.com is a social network site that connects the consumers with small as well as the medium sized designed companies [36].

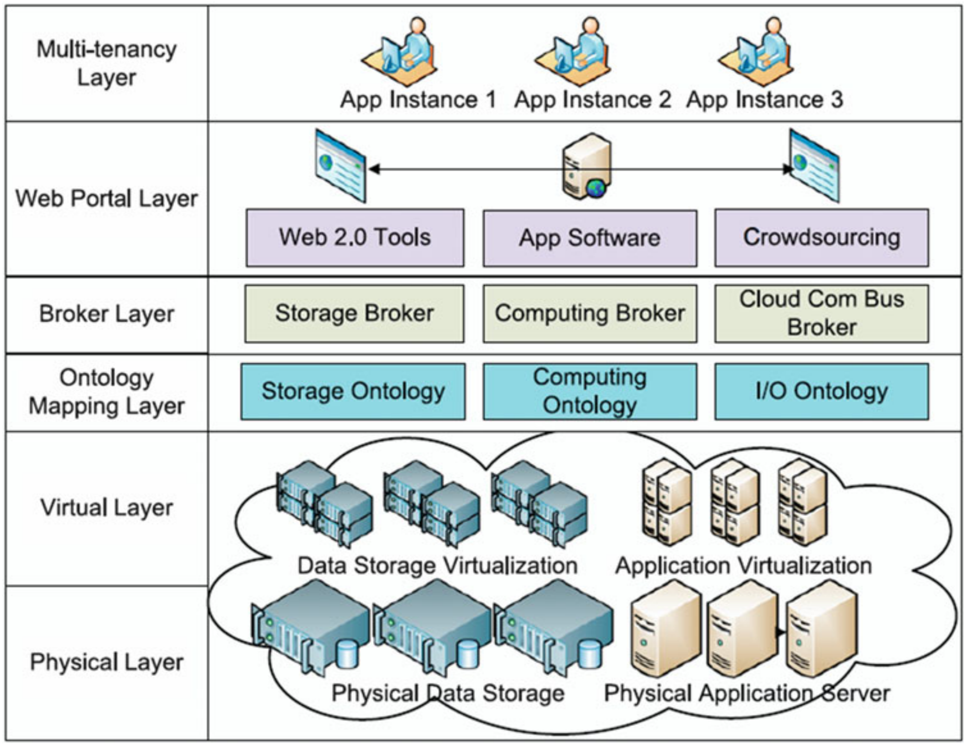


Fig. 7 Features of the social product development

Cloud Based Manufacturing (CBM) The concept of CBM points to a networked manufacturing model which makes use of the on-demand access to a shared collection consisting of a diverse as well as distributed manufacturing resources which can form temporary reconfigurable, production lines that can increase the efficiency, reduce the product lifecycle cost, as well as allow optimal resource allocation as a response to variable demand customer generated tasking.

Quick Parts The quick part can be explained as a cloud based sourcing platform that concentrates over the low volume production for a custom manufactured rapid prototypes. It acts as a bridge between the service consumers and providers via an infant quoting engine that can convert into sourcing process from manual to the real time as well as automated one. Quick part supports users into uploading their CAD data from a variety of commercial CAD software packages e.g. CATIA and solid works. Basing upon the geometric analysis, quick parts is capable of instant generation of a list consisting of qualified service providers that can manufacture these digital models [37, 38]. It is practically a cloud based sourcing platform focusing over achieving high volumes production.

Live Source The concept of live source, pioneered by MFG.com permits service consumers for making requests for quotations that is being sourced by almost 200,000 global service providers. Live source enables the whole of service consumers in order to discover as well as make a collaboration with the quality service providers at small duration of delivery times, giving way to reduced costs as well as more flexible supply chain.

Along with both the cloud based sourcing platforms, 3D Hubs [17, 39], and web based 3D printing platforms assist in establishing a connection between 3D printing service consumers with those of the providers in the local area. In accordance to 3D hubs, majority of the 3D printer owners make use of the devices, for about less than 10 h a week. The aim of these 3D hubs is to allow the 3D printer owners for establishing the social connections within the local 3D printing community in order to raise the use of their device [40]. The concept of 3D hubs as of now has provided an innovative business model which creates as well as delivers values to both the 3D printing service consumers as well as the providers.

3.2 Social Product Development

The concept of social product development does not deal with inventing social related products (i.e. the products which can facilitate the social interactions), in-fact it is all about the developing of the product socially. The social product, social computing technologies regarding the aspects of product development can be interpreted in many ways [1]. The concept of social tool allows a broader pool of people in order to make contributions to product development. The key features for the social product development is about describing as well as qualifying the present crowd, by method of granting or limiting the access, creating the relations within the contributed content along with the experience of contributor and skillset or even establishing the communities in order to practice for certain functional specific collaboration, the web 2.0 tool may be used to obtain feedback from the customers partners, cross functional team members as well as other within the specific crowd. But the freedom is always there with the core product development team to take decision regarding how the feedback can be incorporated into the given feedback [39]. The central concept of the social product development as seen in Fig. 7 is generally aroused by using various social tools in order to improve the value of participants in the product development network [41].

Considering this factual information, the concept of social product development can be defined as "proper use of Web 2.0 technology and patterns of PLM where the social computing can be considered more as an infrastructure upgrades for PLM, specifically for its collaborative pieces".

A product Development/Marketing design where product or service organizations employ engagement or open innovation along with both internal as well as external stakeholders in order to develop both the products or services at different stages of product development life cycle. The crowd sourcing can make itself a part of social product management strategy [15].

The strategy social media marketing combined with the concept of collective intelligence gives way to social product innovations [6, 42]. Open Innovation along with the internet, social media and social technology facilitates the concept of knowledge sharing collaboration, open discussion, relationship building for communities of people, with common interest's needs or problems. Hence it can be said that Social media added to the product development gives social product innovations. Which supports social principles, technologies, that facilitates innovations achieving business goals, product development process etc. [8]. These definitions almost overlap each other with respect to certain aspects that are specific to only to only one definition [43].

Few of the commodities can be drawn from various existing definitions in order to help as well as characterise Social product Development.

1. The social Computing technologies, Social Tools, Social Media utilised influences to a great extent the product life cycle at all stages.
2. A specified crowd that are qualified for internal or external entities
3. The concept of open innovation and crowd sourcing forms example of the social product development, but do not make the definition themselves.
4. Its main goal is towards enhancing the communication value via means like creation of relationship, establishing the communities, and encouraging the collaboration.

The qualified crowd here does not indicate a high ability crowd which is in fact qualified for the task in hand. There are many occasions where an average individual is found absolutely fit for the social product development task [44].

4 Independent and Integrated Cloud Model

The Concept of cloud integration is all about putting together various cloud-based systems into a whole integrated form. The term indicates the joining of a cloud-based systems with other on-premise systems [42]. The main goal of cloud integration is into connecting the divergent elements of various clouds as well as the local resources with a unit environment that is ubiquitous in nature as well as allows the administrators to seamlessly avail as well as manage various applications, data's, services and systems as can be seen in Fig. 8.

The raise in public cloud computing has supported the enterprises in order to use a wide assortment of highly scalable resources and services on demand, instead of constructing as well as maintaining them in-house. However, in certain organisations, the arrival of these diverse resources and services have given way to IT Silos as the management struggle to handle as well as maintain every divergent cloud resources or data set. Without cloud integration, IT administrators have to perform every integration work separately as well as manually, a process which involves time, as well as increase the opportunity for errors [12, 45].

Cloud Integration Platforms and Tools

The organisation can themselves build a customised cloud integration platform themselves, though they might be complex in nature apart from being expensive. Many organisations make use of the third-party integration tool, such as integration platforms like, iPaaS.

4.1 How Cloud Integration Tool Works

The implementation of cloud computing concept cannot be achieved via a single means but include several common

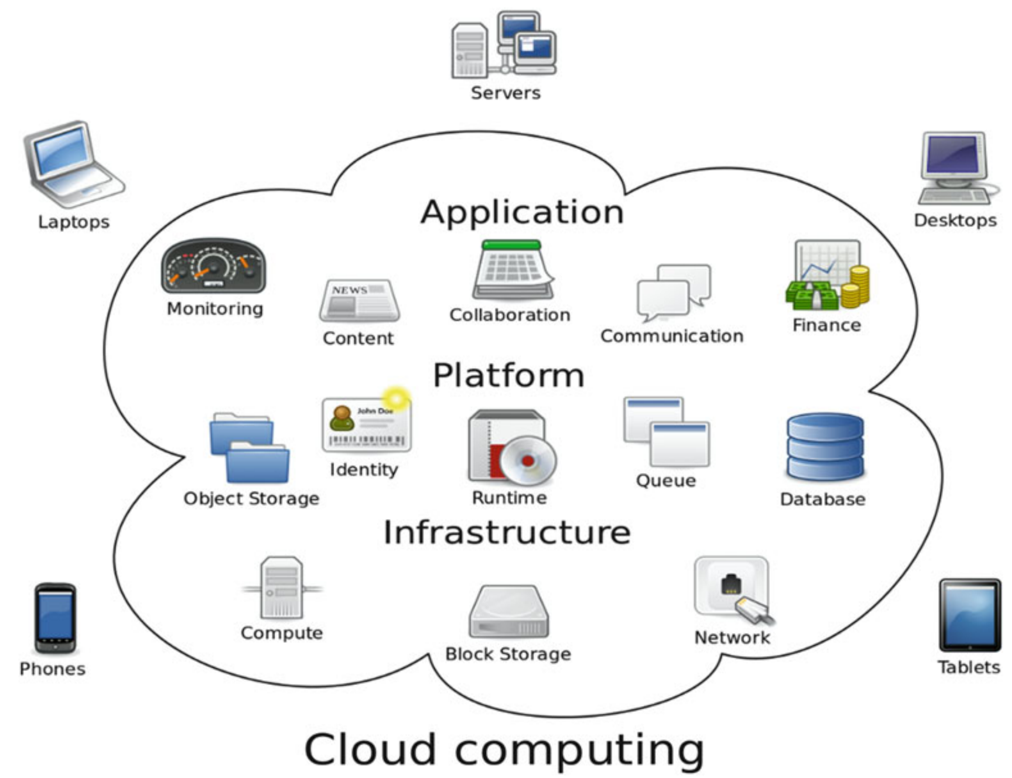


Fig. 8 Integrated cloud computing platform

concepts to be worked upon. E.g. the concept of mediation, or federation, using cloud integration. The mediation is achieved working between the application where the cloud integration platform identifies an event within one application and eventually triggers the response which is transmitted to another connected application [34, 41].

In comparison to mediation federation act as a front end for two or more federation applications where cloud integration platform performs the interception as well as processing the events from outside of these applications triggering the corresponding actions. These two approaches can eventually be combined, such that mediation would handle the actions between applications where as the federation can handle the applications from outside the connected applications.

The cloud integration can be performed by:

1. Asynchronous Method
2. Synchronous Method

Asynchronous Method The synchronous method communicates with both the data as well as commands without the need to wait for a response from the receiving application. The method prevents possible delays while sending or originating as it does not need to wait for the receiver or the target application to respond [42].

Synchronous Method This mode typically has to wait for the arrival of a response from the receiving application ensuring the synchronization of all applications prior to its continuation.

The actual time needed for conducting a process of cloud integration can diverse typically IT organisation which may finish off certain integration tasks like automatic synchronization, fairly fast, where other tasks may need more amount of time, hours days, typically in case the process of synchronization involves a human flow.

The platform of cloud integration makes use of adapters, connectors, etc. which are software modules which communicates with a typical business application. Hence the cloud integration platform may implement a central interface or middle man that can take care of issues like security, authentication when specific adapters adjust to the application that are being integrated. Here the notifications as well as the communications are being performed by the connectors.

Connectors The connectors here may be used for certain specific application e.g. SAP, which may have attributes like being vendor neutral, using Standard Communication Protocols like SMTP message exchanges, Simple Object Access Protocol (SOAP), messaging application program interfaces, (APIs), and Java Connector Architecture (JCA).

For Data integration task the cloud integration platform makes use of an application independent data format, e.g. XML. Here every connector translates the applications specific format, into an independent form prior to any translations or conversions post to which they may exchange the common data with the receiving application.

Types of Cloud Integration The IT team may implement many types of cloud integration which includes:

1. Cloud to Cloud: between cloud platforms
2. Cloud to local: between cloud and on premises environment.
3. Or a mix to both.

The various types of cloud integration tools available in the market are [46–50]:

MuleSoft Anypoint Platform—It adds various tools for the purpose of developing, managing as well as testing Application Programming Interface (APIs).

Dell Boomi—This platform enables the customers for designing a cloud-based integration processes termed as *Atoms* and it transmits data's among the cloud and on-premises applications.

IBM App Connect—the platform allows administrators into setting up the workflows which describes how data is transmitted from one application to another.

Cleo Integration Cloud—the platform provides a digital integration agility across various clouds and on-premise based applications.

Microsoft Azure Logic Apps—It allows the administrators for providing an automated workflow which can integrate the application software's with the data across cloud services and on-premises systems.

Apache Libcloud—it is a Python library that allows the administrators for managing various cloud-based resources via a Unified Application Programming Interface (API).

Benefits and Challenges

Though the cloud integration process don't change any data or perform any modification over the application, it can synchronise data and applications across an enterprise. Once implemented properly, the process of integration may automate complicated work flows along with reducing or eliminating the redundant data which may make way for operational errors. In due course, cloud integration process can improve the operational efficiency, flexibility and scalability as well as lessening the operational costs.

Apart from the stated benefits the cloud integration puts forth some challenges, majority of which arises due to lack of standardization. Currently there has been no universal or a standardized approach in order to integrate the cloud resources and services.

At certain time, make use of various communication schemes which makes it all the more difficult in order to communicate with different elements of the cloud along with the local environment [25]. The updates as well as patches formed over the applications may make changes to way these applications are communicated and may need updates to the time-consuming connectors. There are also additional problems that may cause a disruption to the cloud integration project. The complex form of integrations may need technical expertise and hence is always advisable to have a dedicated staff who can manage it.

5 Sustainable Governance with Wide and Affordable Information Access

The current government of all the developed as well as developing countries have realised the importance of an affordable broadband internet access which can provide a wide range of benefits and opportunities to the new generations in terms of innovative technologies like cloud, Artificial Intelligence, Data Analytics, Internet of Things, etc. Few countries have shown extra need to have this broadband since an affordable internet access is a prerequisite necessity in order to achieve the Sustainable Development Goals (SDGs) adopted by United Nations in 2015 [43].

5.1 The Challenge

Though cloud-based service has become the vital in our daily lives, never the less it demands for a robust, ubiquitous, and affordable broad-band connectivity making it quite critical. There are major gaps which always exist across as well as within countries [20] e.g. internet penetration, which is close to almost 100% in countries like Korea, Saudi Arabia, Qatar, etc. it is estimated that by 2020 only 16% of the world wide population belonging to poor and 3% of global population would be connected to internet. This estimation has failed to meet the expected achievement targeted by Universal Internet Access standard for a low-income nations.

All the more the ongoing popularity of Internet of Things has created a huge demand for Internet Access. Cisco Visual

Network Index (VNI) has forecasted that by 2021 the number of connected devices would increase from 17 billion to 27 billion. A majority of these requirement would need a low-cost wireless connectivity to the cloud through internet.

5.2 Policy Recommendations

A successful closure of existing apps for disjointed ones would require an innovation in policy, technology as well as the business model. The size of existing gap indicates, that it cannot be simply closed via business in a casual manner. There are few policies which create obstacle for investment by favouring the particular technology industrial sector or incumbent. The various regulations supporting the business models should be used else in fact may result in no-competition, poor service, as well as high prices. Here with the acceleration in the pace of change and agility, it becomes necessary for current policy makers. Here the forth coming challenge is how to develop the appropriate enabling environment that could give way to sustainable growth. In order to achieve this the promotion of the following is needed [38].

Policy Innovation

For the programs related to expansion of internet access the related laws need to be reformed in order to enhance the programs. Various initiatives like alliance for obtaining affordable internet UN broadband commission for a sustainable development along with the I-world connected project plays vital role in the process of highlighting for example policy innovation around the world would assist the policy makers for understanding why certain countries are succeeding in order to make the internet access more affordable [29, 38]. The process of innovation incurs simulating the competition, eradicating the financial barriers, alteration of tax policy, migration of government services and much more. Here both creation of open as well as a competing broadband market provides a market in respective countries should be a core policy objective and it must mean that policies must remove obstacles that limits opportunities that provide access and are vitally important.

Technology Innovation

Here the technology is under rapid change which is quite an evident in wireless communications. Here the ability to harness spectrum from broadband moved over exponentially in a few decades in collaboration with certain technology which is able to provide gigabytes per second connectivity. Hence access to spectrum suffers obstacle by a regulatory model which was evolved at its nascent phase over a century ago. It was optimised around exclusive usage of license protected by swathe of unused spectrum as a buffer from potential interference. Though the model is apt for certain kinds of services, the current technologies allow the sharing of spectrum, that gives an outcome of bigger reuse of the spectrum at a lower cost which improves an access for all. Currently more than half of the world's internet traffic is through unlicensed and shared spectrum. The policy makers should put effort in order to accelerate the time for deployment of these recent technologies while reviewing as well as revising their approach to the spectrum [41].

Spectrum Management

The policy makers here are needed to accelerate the efforts in order to start new low-mid as well as high frequency bands for both kind of license as well as unlicensed use. The TV white space is quite an example of the technological innovation pertaining to the areas of low band spectrum controlled by the data bases, in case of an unlicensed access to the TV white space provides affordable internet connectivity in the current era across the several countries where regulators do allows it without incurring any harmful interference to any protected service [41]. Here the unlicensed spectrum is comparatively less in cost than the licensed spectrum since there are no auctions or any licensing fee that needs to be considered into account for an operator's business model that enables more rapid as well as low cost deployment scenarios. Considering the spectrum from the deployment results in the artificial scarcity that may tend to high price for access. Here the policy makers need to ensure that any spectrum licensed on the basis of special cause can be explored through 'use it or lose it' policy. The spectrum regulators can also adopt the policies which can support the sharing of underutilised spectrum as a massive resource as the digital fuels to the digital economy.

Business Model Innovation

The current condition of a telecommunication landscape is quite variant from the one in the past, when national monopoly careers have launched the circuit switched voice services with that of the treaty based international connections. The current environment consists of numerous public as well as the private networks that are interconnected through a wide range of the commercial agreements [39]. The current internet network build up is in fact an enabler for a digital transformation of business, government as well as leisure. Here the policy environment actually invites the experimentation over a newly developed business models as well as the partnerships, where unique conversions can be seen occurring, e.g. impact of mobile money in countries like, Africa. The policy makers must be on the process of look out for the policy as well as regulation which can carry out with such innovations.

Explaining this factor in finance sector, various governments have levied rules and restrictions over the foreign investments in the field of telecommunications, mobile as well as broadband infrastructure, and have also imposed various other investment policies which can put constraints on the process of entrepreneurs looking for establishing themselves in the market. Policies which support the concept of public-private partnerships and understands the structural requirements of various funding institutions are required to facilitate the access to capital [45].

Moreover, in majority of countries, broadband access is considered to be a as a luxury need which serves as counterproductive since it reduces investment that is contributed for its infrastructural development on the other hand increasing its cost of access, along with underestimating the importance of broadband access in its utility towards day to day services. These kind of policies are interested to contribute into widening of economy as well as divide socially. Here the Policymakers should adopt tax policies which stimulate the rapid investment into and adoption of the connectivity solutions which can optimize the taxation regimes that can help them in achieving the goals designed to establish the connectivity aspect.

The Policymakers here play the role of being innovative while adopting telecommunications policies which on the other hand reduces unnecessary regulation pertaining to services along with triggering the competitiveness. It supports the underlying goals of access and adoption [44, 45]. Example, reformation of universal services, and funds in order to incorporate the funding for broadband, assuring of net neutrality, triggering innovativeness in services, and reducing the regulatory burden over the operators that are all overall quite helpful. On the other hand, the growth of regulators with freedom attained from regulatory capture, both are quite critical for stimulating the investment.

Finally, it can be stated that there are quite a number of modes which can stimulate as well as accelerate both investment and deployment, e.g. "dig once" policies that ensures new highway and rail infrastructure projects which includes channels designed for covering fibre optics. In addition, infrastructures that shares the transmission towers can avoid redundancy of any form. The Demand-side stimulation obtained through deploying online government services along with the growth of content and services relevant to the local mass may contribute to certain extent [45].

6 Conclusion

Cloud is currently a vital aspect of the technical growth in the society where, majority of industries and services rely over it to carry in major day to day activities. With uplift of technology and growth of digitization all over the world, many industrial organizations have incorporated the electronic and digital mode of work management, and depends greatly over the recent technologies in order to enhance its productivity.

The chapter primarily concentrates over the contribution of cloud computing over the various industrial sectors. It discusses on the cloud infrastructure for industries. Further, it presents various framework for its production which includes design, manufacturing as well as the social product development. The chapter discusses the various independent as well as integrated cloud models and finally the government undertakings to provide the internet services in a cost-effective manner.

With the growth of various recent sectors in field of cloud technology, it has provided the industry with various benefits of shedding the overhead of having hardware infrastructure to support the various IT related work.

References

1. Singh, S. P., Nayyar, A., Kaur, H., & Singla, A. (2019). Dynamic Task Scheduling using Balanced VM Allocation Policy for Fog Computing Platforms. *Scalable Computing: Practice and Experience*, *20*(2), 433-456.
2. Kaur, A., Gupta, P., Singh, M., & Nayyar, A. (2019). Data Placement in Era of Cloud Computing: a Survey, Taxonomy and Open Research Issues. *Scalable Computing: Practice and Experience*, *20*(2), 377-398.
3. Singh, P., Gupta, P., Jyoti, K., & Nayyar, A. (2019). Research on Auto-Scaling of Web Applications in Cloud: Survey, Trends and Future Directions. *Scalable Computing: Practice and Experience*, *20*(2), 399-432.
4. Singh, S. P., Nayyar, A., Kumar, R., & Sharma, A. (2019). Fog computing: from architecture to edge computing and big data processing. *The Journal of Supercomputing*, *75*(4), 2070-2105.
5. Das, S., & Nayyar, A. (2019). Innovative Ideas to Manage Urban Traffic Congestion in Cognitive Cities. In *Driving the Development, Management, and Sustainability of Cognitive Cities* (pp. 139-162). IGI Global.
6. Nayyar, A., Jain, R., Mahapatra, B., & Singh, A. (2019). Cyber Security Challenges for Smart Cities. In *Driving the Development, Management, and Sustainability of Cognitive Cities* (pp. 27-54). IGI Global.
7. Solanki, A., & Nayyar, A. (2019). Green Internet of Things (G-IoT): ICT Technologies, Principles, Applications, Projects, and Challenges. In *Handbook of Research on Big Data and the IoT* (pp. 379-405). IGI Global.
8. Batth, R. S., Nayyar, A., & Nagpal, A. (2018, August). Internet of Robotic Things: Driving Intelligent Robotics of Future-Concept,

Architecture, Applications and Technologies. In *2018 4th International Conference on Computing Sciences (ICCS)* pp. 151-160. IEEE.
9. Nayyar, A., Puri, V., & Le, D. N. (2017). Internet of nano things (IoNT): Next evolutionary step in nanotechnology. *Nanoscience and Nanotechnology*, *7*(1), 4-8.
10. Foster, I., Zhao, Y., Raicu, I., Lu, S. (2008). Cloud computing and grid computing 360-degree compared. *In: Grid computing environments workshop, Austin*.
11. Putnik, G., Sluga, A., ElMaraghy, H., Teti, R., Koren, Y., Tolio, T. et al. (2013). Scalability in manufacturing systems design and operation: state-of-the-art and future developments roadmap. *CIRP Ann*.
12. Wu, D., Thames, J.L., Rosen, D.W., Schaefer, D. (2013). Enhancing the product realization process with cloud-based design and manufacturing systems. *ASME, Journal of Computing & Information Science in Engineering*, 13(4). (https://doi.org/10.1115/1.4025257). [Accessed on August, 2018]
13. Fuh, J.Y., Li, W.D. (2005). Advances in collaborative CAD: the-state-of-the art. *Computer Aided Design*, 37(5), pp. 571–81.
14. Fan, L.Q., Senthil Kumar, A., Jagdish, B.N. (2008). Bok SH. Development of a distributed collaborative design framework within peer-to-peer environment. *Computer Aided Design*, 40(9), Pp. 891–904.
15. Mahdjoub, M., Monticolo, D., Gomes, S., Sagot, J.C. (2010). A collaborative design for usability approach supported by virtual Reality and a multi-agent system embedded in a PLM environment. *Computer Aided Design*, 42(5), Pp. 402–13.
16. Wu, D., Rosen, D.W., Schaefer, D. (2014). Cloud-based design and manufacturing: status and promise. *In: Schaefer D, editor. Cloud-based design and manufacturing: a service-oriented product development paradigm for the 21st century, London, UK: Springer*, pp. 282.
17. Autodesk, 2014. (Retrieved from http://www.123dapp.com/). [Accessed on October, 2018]
18. Autodesk, 2014. (Retrieved from https://www.autocad360.com/). [Accessed on September, 2018]
19. Wu, D., Thames, J.L., Rosen, D.W., Schaefer, D. (2012). Towards a cloud-based design and manufacturing paradigm: looking backward, looking forward. *In: Proceedings of the ASME 2012 international design engineering technical conference & computers and information in engineering conference (IDETC/CIE12)*.
20. L. Zhang, Y.L. Luo, F. Tao, B. H. Li, L. Ren, X.S. Zhang, H. Guo, Y. Cheng, A.R. Hu. (2012). Cloud manufacturing: a new manufacturing paradigm. *Enterprise Information Systems*.
21. Tao, F., Zhang, L., Venkatesh, V. C., Luo, Y., & Cheng, Y. (2011). Cloud manufacturing: A computing and service-oriented manufacturing model. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 225*(10), 1969–1976.
22. Wu, D., Schaefer, D., & Rosen, D.W. (2013). Cloud-Based Design and Manufacturing Systems: A Social Network Analysis. *International Conference on Engineering Design (ICED13), Seoul, Korea*.
23. Wu, D., Greer, M.J., Rosen, D.W., & Schaefer, D. (2013). Cloud Manufacturing: Drivers, Current Status, and Future Trends. Proceedings of the ASME 2013 International Manufacturing Science and Engineering Conference (MSEC13).
24. Wu, D., Greer, M. J., Rosen, D. W., & Schaefer, D. (2013). Cloud manufacturing: Strategic vision and state-of-the-art. *Journal of Manufacturing Systems, 32*(4), 564–579.
25. Schaefer, D. (Ed). (2014). Cloud-based design and manufacturing (CBDM): a service-oriented product development paradigm for the 21st century, Springer, London, UK.
26. Schaefer, D. (Ed.). (2014). Product development in the Socio-sphere, Springer, pp. 235.
27. Sudarsanam, S. K., & Umasankar, V. (2019). Cloud-based design and manufacturing. In *Global virtual enterprises in cloud computing environments* (pp. 202-230). IGI Global.
28. Wang, W., & Koren, Y. (2012). Scalability planning for reconfigurable manufacturing systems. *Journal of Manufacturing Systems, 31*(2), 83–91.
29. Wu, D., Rosen, D.W., Wang, L., & Schaefer, D. (2014). Cloud-Based Manufacturing: Old Wine in New Bottles? *Proceedings of the 47th CIRP Conference on Manufacturing Systems, Windsor, Canada*, pp. 94-99. (doi:https://doi.org/10.1016/j.procir.2014.01.035) [Accessed on October, 2018]
30. Li, B. H., Zhang, L., Wang, S. L., Tao, F., Cao, J. W., Jiang, X. D., ... & Chai, X. D. (2010). Cloud manufacturing: A new service-oriented networked manufacturing model. *Computer Integrated Manufacturing Systems, 16*(1), 1–7.
31. K. Kurelovi, S. Rako and J. Tomljanovi. (2013). Cloud Computing in Education and Student's Needs. *MIPRO,* pp. 856-861.
32. N. Leavitt. (2009). Is cloud computing really ready for prime time? *Computer,* 42 (1), pp. 1520.
33. J. Naughton. (2009). Theres silver lining to Googles cloud computing glitch. The Observer. (Retrieved at: https://www.theguardian.com/technology/2009/mar/01/gmailoutage-cloud-computing) [Accessed on November, 2018]
34. C. Bulla, B. Hunshal, and S. Mehta. (2016). Adoption of Cloud Computing in Education System: A Survey. *International Journal of Engineering Science and Computing*, vol. 6(6), pp. 6375.
35. Autodesk, 2014. (Retrieved from https://www.autocad360.com/). [Accessed on September 2018]
36. 100kgarages.com, 2014. (Retrieved from http://100kgarages.com/). [Accessed on September, 2018]
37. Naik, A., Ajay, A., Kolhatkar, S. (2013). Applicability of cloud computing in academia. Indian Journal of Computer Science Engineering, vol. 4 (1).
38. Alshuwaier, F., Alshwaier, A., Areshey, A. (2012). Applications of cloud computing in education, Computing and Networking Technology. *8th International Conference on. IEEE (ICCNT).*
39. Lakshminarayanan, R., Kumar, B., Raju, M. (2014). Cloud Computing Benefits for Educational Institutions. *Information Security and Computer Fraud*, vol. 2 (1), pp. 5-9.
40. Dong, B., Zheng, Q., Qiao, M., Shu, J., Yang, J. (2009). Blue Sky Cloud Framework: An Elearning Framework Embracing Cloud Computing. LNCS, vol. 5931, pp. 577-582. (Retrieved at: 1-AW91J/images/Five Steps to Successful Integrated Cloud Management IDC.pdf) [Accessed on October, 2018]
41. Kasi, D., Kusuma, S., Kumar, S. (2012). Cloud Computing Issues and Benefits Modern Education. *Global Journal of Computer Science and Technology Cloud Distributed*, vol. 12(10), pp. 1-7.
42. Ghazizadeh, A. (2012). Cloud Computing Benefits and Architecture in E-Learning. Wireless, Mobile and Ubiquitous Technology in Education. I.E. Seventh International Conference, IEEE, pp. 199-201.
43. Tashkandi, A., Al-Jabri, I. (2015). Cloud computing adoption by higher education institutions in Saudi Arabia: an exploratory study. *Cluster Computing*, vol. 18(4), pp. 1527-1537.
44. Al-Asmari, Rabb Khan. (2014). E-learning in Saudi Arabia: Past, present and future. *Near and Middle Eastern Journal of Research in Education*, vol. 2(1), pp. 1-11.

45. S. Ashtar, A. Eydgahi. (2010). Student Perceptions of Cloud Communication. UNESCO Institute, putting Effectiveness in Higher Education in Computational. (Retrieved at: Sci http://iite.unesco.org/pics/publications/en/files/3214674.pdf) [Accessed on December, 2018]
46. T. Bittman. (2009). Cloud Computing Inquiries at Gartner. (Retrieved at: http://blogs.gartner.com/thomasbittman/2009/10/29/cloud – computing – inquiries – at – gartner/) [Accessed on March, 2019]
47. Mallikharjuna, Rao, N. Sasidhar, C. Satyendra, Kumar, V. (2010). Cloud Computing Through Mobile-Learning. *International Journal of Advanced Computer Science and Applications*. Vol. 1(6), pp. 42-46.
48. Adamson, G., Wang, L., Holm, M., & Moore, P. (2017). Cloud manufacturing–a critical review of recent development and future trends. *International Journal of Computer Integrated Manufacturing, 30*(4-5), 347–380.
49. Kop, R., Carroll, F. (2011). Cloud Computing and Creativity: Learning on a Massive Open Online Course. *European Journal of Open, Distance and E-Learning*, (Retrieved at: http://www.eurodl.org/?p=specialsp=articlesarticle=457) [Accessed on February, 2019]
50. Sultan, N. (2010). Cloud computing for education: a new dawn? *International Journal of Information Management*, Vol. 30(2), pp. 109-116.

Bandana Mahapatra is an Asst. Professor in School of Data Science, Symbiosis Skills and open University, Pune, Maharashtra, India since 2008. She Completed her Ph.D. in Computer Science and Engineering from Siksha 'O' Anusandhan University, Bhubaneswar in year 2018. She completed her masters from Biju Patnaik University of Technology, Bhubaneswar in year 2008. She completed her Bachelors of Engineering Degree in year 2005. She has presented many papers in International conferences and published many Peer-reviewed journals and chapters in reputed publications. Her research interest is Security in AdHoc Network and Artificial Intelligence. Her contribution also includes various Issues in Adhoc Network like efficient power management or searching shortest path for communication using artificial intelligence.

Modeling and Simulation for Industry 4.0

Rajalakshmi Krishnamurthi and Adarsh Kumar

Abstract

The recent growth in the industry sector has prominent role of technology towards the automation in terms of computing systems and software products. The objective of Industry4.0 is automation of industry process through integration of service-oriented architecture, intelligence mechanism, proactive maintenance systems. The key areas such Robotics and 3D modeling has attracted lot research and innovation happening in Industry 4.0 concepts. This chapter presents the various modeling and simulation techniques for Industry 4.0. In the first part, the modelling techniques that are existing in literature are discussed. It is observed that, there are 16 modelling techniques possible to address the Industry 4.0. The commonly used ones like SysML, UML, metamodel, Production Flow Scheme and Ontology based context modeling are presented in detail. The second part of the chapter is focused on simulation mechanism for Industry 4.0. In this Simulation Optimization methods and its Applications are discussed. Further, how efficiently the Industry 4.0 concepts can be optimized by various parameters and performance metrics are presented.

Keywords

Robotics · 3D modeling · UML · SysML · Production flow scheme · Ontology · Optimization

R. Krishnamurthi (✉)
Department of Computer Science, Jaypee Institute of Information Technology, Noida, India
e-mail: k.rajalakshmi@jiit.ac.in

A. Kumar
Department of Systemics, School of Computer Science, The University of Petroleum and Energy Studies, Dehradun, India
e-mail: adarsh.kumar@ddn.upes.ac.in

1 Introduction

The industry sector is one of the predominant foundations of economic growth of a nation. Today, it is essential that the industry sector operations are automated along with computing systems and software platforms. To reminisce, there exist three developmental stages of integration of technology with Industrial processes namely traditional models of automation, embedded system based Industrial automation, Intelligent based automation. In traditional models of automation constitute proprietary developed protocols for integration of manufacturing process with various business processes. In this model, the eBusiness models are consider as external systems that can perform various business-oriented process. Example of these models is ModBus, AS-I, Process Field Bus (PROFIBUS), Industrial Ethernet (PROFINET). In embedded systems based developmental stage, involves integration of Ethernet and TCP/IP protocol suite to connect with remote web servers. The main objective at this stage was to achieve transparent factory in terms of production, processing, maintenance of Industrial subsystems. Finally, in intelligent based automation, the focus is Service Oriented Architecture (SOAP), incorporating intelligence, self-management of industry subsystems, proactive maintenance of various components of processing units by using embedded devices and control systems. These device functionalities are further integrated with Enterprise Resource Planning Software Systems (ERP). According to European Research Projects [1, 2], the convergent approach of the SOA and embedded devices as advantageous industrial process automation technologies.

The trending proliferation of Industry 4.0 and design goals are greatly facilitated by Model Based System Engineering (MBSE). The primary objective of Industry 4.0 is to integrate process automation system and its stakeholders within the value-added chain at low cost and less time. In order to meet the requirement of analytics and emergence of intelligence capability with in business, there is need to enhance

A. Nayyar, A. Kumar (eds.), *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-14544-6_7

mechanism of human to machine interactions and transferring of digital commands into physical Industrial scenario. The areas like intelligent robotics and 3D printing are on way to realise these objectives of Industry 4.0. According to authors in [3], the four design goals of MBSE Industry 4.0 are interoperability, technical assistance, transparency in information and decision making in decentralized manner. Interoperability defines the way of interconnection between sensors, devices, manufacturing systems, and people. The assistance in technical aspect ensures understanding of the motivation and complexity of Industry 4.0 processes and systems. Transparency in Information defines the runtime data handling through queries and information processes based on the data collected form wide range of sensors. Decision making defines the mechanism to enable interconnection among varied autonomous control systems. According to authors in [4], the challenges encountered in software engineering form perspective of Industry 4.0 are modularized approach for interfaces and maintenance of such interfaces, tracking system to identify changes in the wide range of heterogeneous and distributed industrial machineries, the consistency of data, software irrespective of variants, and adaptation of algorithms and mechanisms to the huge data handling through Big Data [5].

RAMI4.0

RAMI4.0 stands for Reference Architecture Model for Industry 4.0. It is a 3D mapping reference to provide various solutions to achieve Industry4.0 concept. The several individual components of Industry 4.0 are integrated in a common framework, in order to provide better understanding of relation among these components. It also represents coordinated systems for different types of branches in Industry. Three main axis of RAMI 4.0 Architecture are life cycle and value Stream, Hierarchy level and Layers, as depicted in Fig. 1.

- **Life cycle and Value stream**: This axis represents the life cycle of various entities of Industry 4.0. The entities are physical parts of plants, products and various control system of plants. The IEC 62890 standard is followed in this layer. The standards incorporate mechanism to manage the manufacturing of products in Industry.
- **Hierarchy level**: This axis follows the international standard IEC6224. The objective is to establish the various Industry control systems through regulated integration process.
- **Layers**: This axis consists of six layers that are stacked vertically. The various Industry 4.0 components as called as physical assets. The objective of these layers is to map these varieties of physical assets into their corresponding digital or virtual representation. Further, each individual layer defines various functionalities of each component that are associated within a system of Industry 4.0. In order to ensure that the specification of each component must be in consistency with Industry Standards, it is necessary to have techniques while modeling and designing of components.

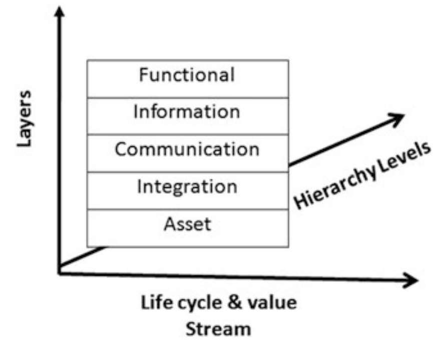


Fig. 1 RAMI 4.0 Model

2 Modern Design and Virtual Prototyping

According to authors in [3] there are 16 modelling techniques possible to address the Industry 4.0. They are 3D Modeling, Architectural Descriptive Language (ADL), Automation ML (AML), Business Process Modeling (BPM), Core Manufacturing Simulation Data (CMSD), Domain specific languages (DSL), Entity Relation Model (ER Model), Petri Nets and Priced Timed Automata (PN and PTA), General Programming Languages (GPL), Knowledge Representation using OWL, Meta modeling techniques, SimuLink/MATALB, SysML, UML, XML. Figure 2 represents the most commonly used modeling techniques in Industry 4.0.

2.1 SysML

This section discusses the SysML based modeling concerning to Industry 4.0. The primary activities of SysML are (1) composition of basic functional requirements (2) identification of various aspects of Industry 4.0 and the perform process modeling (3) specification elaboration of each data elements (4) consistency validation for all process models.

- **Composition of basic functional requirements**
  The composition of requirements provides description of each requirements in a semi-formal way. Basically,

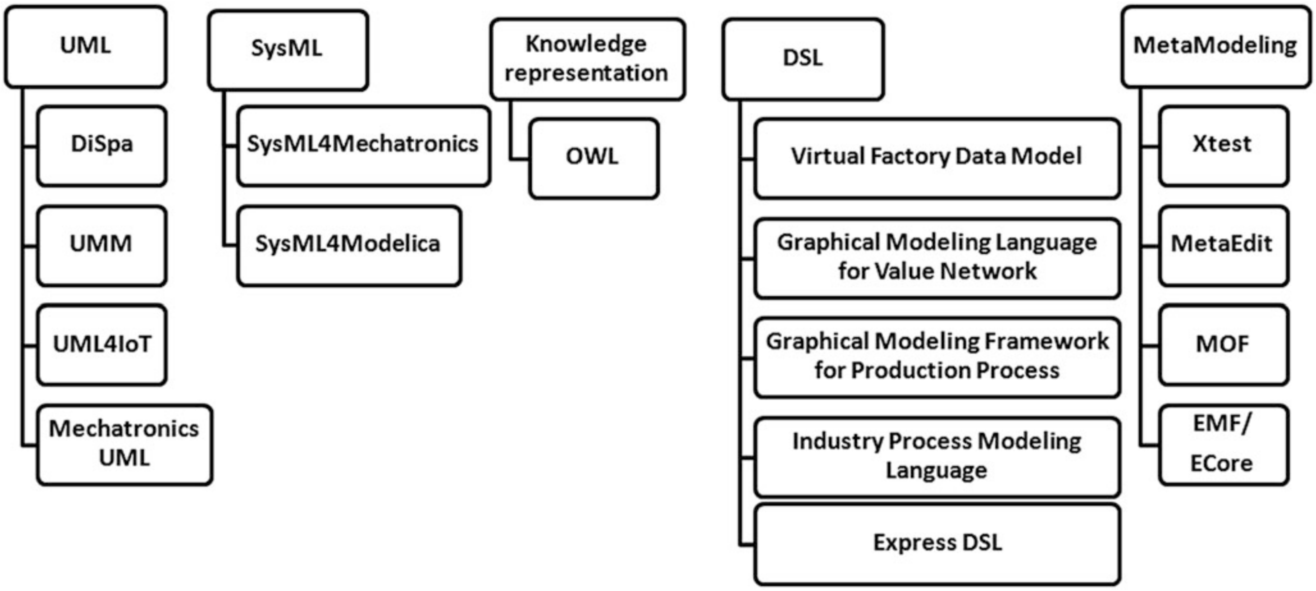


Fig. 2 Common modeling techniques for Industry 4.0

the requirement specifications in SysML are in the form of hierarchical, chart models or table format of the different requirements. As discussed in [6], the requirement specifications are in the visual representation using UML based use case diagrams, as depicted in Fig. 3.

- **Identification of various aspects of Industry 4.0 and the perform process modeling**:
  The primary objective of SysML requirement specification is to enable detailed information and analysis of Industry 4.0 concepts [2, 7]. Some of the identified Industry 4.0 concepts in the conveyor belt operation of mining site are depicted in Fig. 3.

  IoT devices: Generally, the actors or associated subsystems are the components that are consider as the IoT devices. In the example of conveyor belt, the sensors devices that monitor and gather information about the operation of belt are considered as IoT devices.

  IoT operations: The IoT sensor devices have the objective to monitor and gather information from the surrounding physical environment. Thus actuation and sensing are the primary operations of these IoT devices. In our example, the sensor of conveyor belt has dedicated IoT operations.

  Data Buffering: In data buffering, the sensed data of IoT devices are buffered temporarily based on the different use case requirements. In case of conveyor belt, IoT operations of the belt are buffered locally so that can be stored into the remote cloud server.

  Data Storing: The persistent real world sensed data are verified. Then these IoT device data are stored on the private remote cloud data store.

  Data Accessing: Authorized or trusted services are involved in order to access various data from the private remote cloud data store.

  The example of conveyor belt at a mining site demonstrates the need of industry process modeling based management in order to deal the mission critical industry process, data handling, components management, varied Industry 4.0 users, and complex flow of IoT operations.

- **Specification elaboration of each data elements**
  Next step is to elaborate each of the data elements using UML based class models. The class models are generally domain specific. The domain specific class model incorporates various aspect of Industry 4.0 such as data set for each of the IoT devices. Based on class model, the process models are performed. further, the constraints are specified in order to maintain the consistency of each data flow.

- **Consistency validation for all process models**
  The objective of process models is to preserve the consistence and the correctness among different data elements. Hence, the reviews are performed at each level of overall SysML modeling. It is essential to study and analysis impact of correctness on a specific model or data elements, as the data elements are interconnected directed or indirectly to one other. In fact, repetitive analysis of the correctness is performed to ensure less negative impacts among data elements.

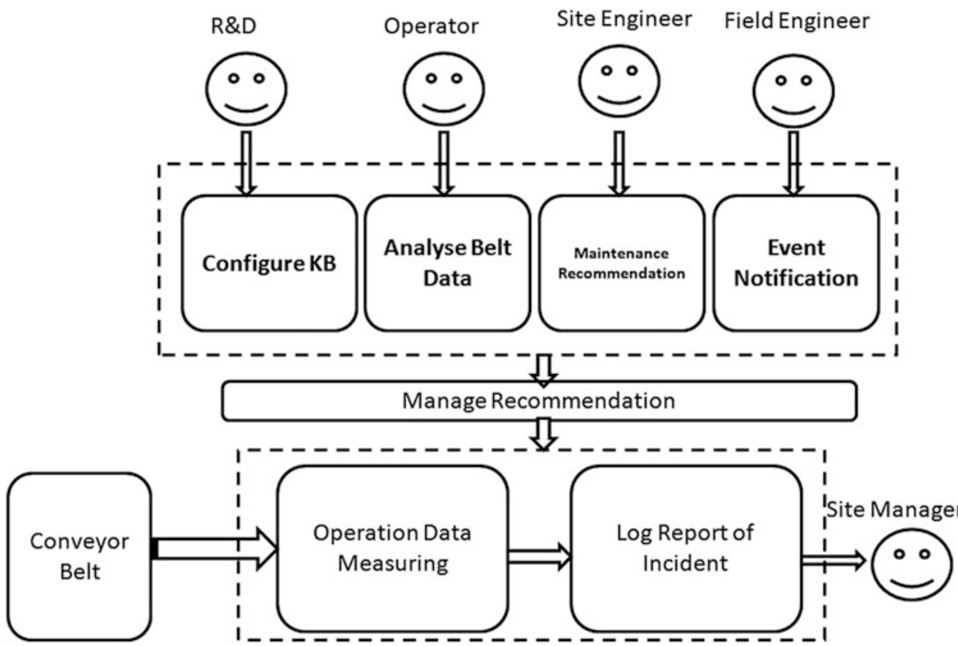


Fig. 3 Use case diagram for SysML Requirements depicting Conveyor belt operation at a mining site

2.2 Production Flow Scheme/Petri Nets

The production flow scheme (PFS) is used to model the discrete event systems (DES) [8–10]. PFS is a graph-based process interpretation using Petri Net (PN). The PFS/PN consists of various process activities as per the specification and flow between the activities, and is specified at the abstract level. The objectives of the PFS are to perform modeling the process activities based on the detailed functionality of each component involved in Industry 4.0. Further, the PFS/PN is used to model the functional flow between different system processes that involved at different levels of software, hardware components of Industry 4.0. The PFS/PN modeling ensures correctness and consistency of modeling at compliance to the specification of RAMI4.0 standards. For this purpose, generally high-level programming languages are used. This provides platform independency in terms of technology as well as diverse industries. In fact, it also provides flexibility in designing the various system specific processes. It is user friendly, less complex and can be used by any professionals like engineers, designers or architects. The primary characteristics of PFS/PN based modeling are that ability to model at micro levels as well as macro level. The micro level components like raw materials, tools, machines, products can be modelled. Similarly, at the macro level, sequence of execution control instructions, data handling and application services. The basic components of PFS are activity, flow arcs and the distributors. The activity components of PFS represent the various elements that are passive within systems. The flow arcs represent the process flow between two different items within the same system. The flow arcs comprise of three types namely primary, secondary and integration flow. The flow represents the interaction between different component levels like request, process and response functions. Figure 4 depicts the basic structure of PFS/PN.

The control structures of various items are interconnected through activity flow arcs with respect to the specification of each items involved in the process modeling. There are six types of PFS/PN models name sequential, concurrent, conditional, iterative, and parallel and synchronization. Basically, in PFS/PN, the system process modeling involves combination of PFS and PN models or simply based on PN models. However, the system process modeling begins with abstract representation at higher level. Consecutively, the flow is followed by detailed and refined modeling at each basic level. Figure 5 depicts the basic modeling cases for PFS/PN.

2.3 Business Process Modeling

The basic behavioural notions of the various functional elements of the systems are described in business process models (BPM) [11, 12]. The modelling are performed based on the formal requirements of the functional elements at early stages of the design phase. The architectures frameworks such as Reference Model of Open Distributed Processing (RM-ODP), Federal Enterprise Architecture Framework (FEAF), Object Management Group—Model Driven

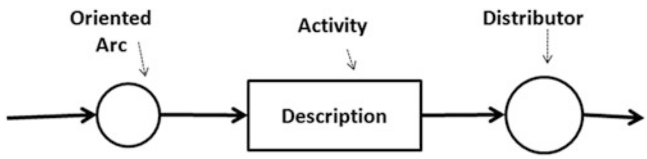


Fig. 4 Basic elements of PFS/PN structure

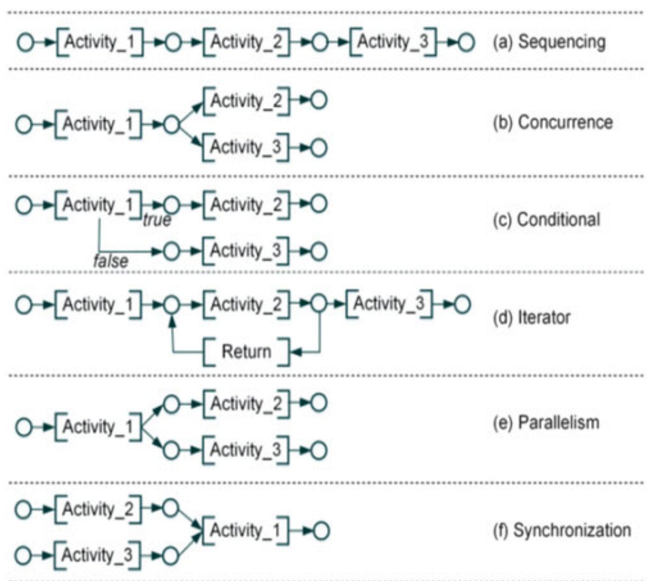


Fig. 5 Basic structures of PFS/PN modeling

Architecture (OMG-MDA), The Open Group Architecture Framework (TOGAF), incorporate process modeling. Table 1 depicts the major architectural frame works with corresponding scope of models.

The BPM model has primary elements such as tasks, events and data elements. The tasks include send, receive and service operations. The language used by the BPM is Industry 4.0 process Modeling language (I4PML). Moreover, the process model incorporating the Internet of Things needs language extension to the existing Industry 4.0. For this purpose, process architecture such as Internet of Things Architecture (IoT-A) is provided as extension to the BPM. The process icon used for I4PML profiling in BPM modeling includes mobility aspect, actuation task, sensing task, IoT devices, human computer interactions, device data object, data storage, and cloud applications as depicted in Fig. 6.

2.4 Industry 4.0 Process Modeling Method (I4PMM)

According to authors in [13] in the modern era, the manufacturing industry system is amalgamation of cyber, cyber physical system, and human experts. Further, the Internet of Things is enhancing this amalgamation of manufacturing system components through cyber based interfaces [14–18]. However, the customers expect the products for their individual needs at low cost, irrespective of the critical process of manufacturing. On the other hand, the traditional methods of developing various system components of manufacturing process are not sufficient to the demand of the customers. Because, in tradition way, the manufacturing system comprises three basic components namely the physical real plant, interconnected computing systems, and the controller for physical systems to monitor the manufacturing process. Moreover, the enhancement in manufacturing process in traditional approach is limited by independent development of the above basic three components. Thus, the traditional approach of independent components is not sufficient to meet the requirement of demanding customizable customer needs [19–25]. Hence, the manufacturing process requires flexible, dependable, predictable and cooperative system components, where the physical plant parts highly couple with corresponding cyber physical systems and IoT systems. The UML based Industry 4.0 Process Modeling Method (I4PMM) design specification for the cyber physical part of the mechatronics parts of the manufacturing system seem promising solution to the above product customization problem. Basically, the UML based Industry 4.0 Process Modeling Method (I4PMM) modelling of mechatronic components enable the automation of manufacturing process along with compliance of IoT standards through interfaces known Industrial Automation Things (IAT) [26–28].

2.5 Metamodeling

The core aim of the Industry 4.0 concept is to enhance the potential of knowledge generation through the manufacturing process and predict the outcomes of the manufacturing beforehand. The interest of "Smart Factory" systems is

Table 1 Industry 4.0 architectural frameworks

Sl.	Architecture	Model
1	Reference Model of Open Distributed Processing (RM-ODP)	Enterprise and Computational Viewpoint Model
2	Federal Enterprise Architecture Framework (FEAF)	Business Reference Model
3	Object Management Group—Model Driven Architecture (OMG-MDA)	Platform Independent Model
4	The Open Group Architecture Framework (TOGAF)	Business Architecture Model

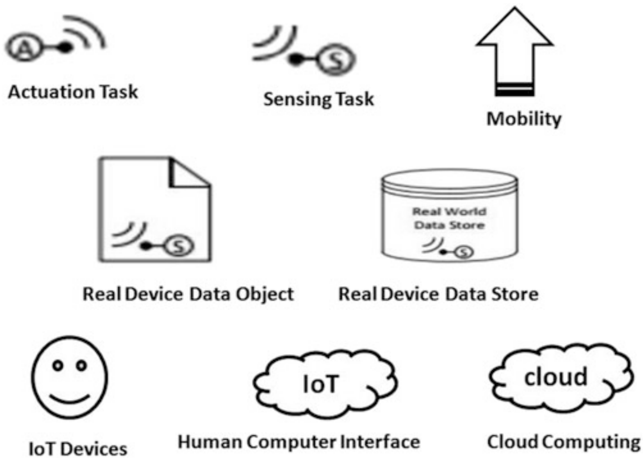


Fig. 6 Element icons of I4PML

related to the high performance with low cost investment in information processing and communication technologies. Hence necessitates renewing the earlier methods of manufacturing technology. The solution to this are listed as (1) to improve the usage of different aspects of knowledge domains in industry (2) gradual enhancement to the advanced technologies instead of replacing the entire manufacturing systems (3) to utilize the user-friendly solution to adapt industry 4.0 (4) to provide interoperability among different legacy software systems (5) to provide enhance context based view of interaction between manufacturing hardware and the software solutions. Thus, the two main requirements to achieve the concept of Industry 4.0 are (1) knowledge representation and (2) adaptability. The knowledge representation based I4.0 target to minimize the human intervention and automate integration of different system interfaces with minimal expert opinion, and to satisfy the I4.0 concept requirements. The adaptability of different I4.0 solutions deals with flexibility to permit a gradual incorporation of advanced technologies within the existing systems [29–32]. Basically, it targets to maximize the reutilization of existing systems even in case of adding advanced components as system solutions. These features of Industry 4.0 are possible only with incorporating Meta model representation of knowledge about data, flow and system involved in Industry. This means that industry with one centralized Meta model with different types of industry applications interconnected based on the Meta model. Generally, these applications have varied specifications and objectives to be performed. In [33], addressed the enhanced mechanism of knowledge representation, system communications and compliances of various industry standards across the production process. Authors [34, 35] discussed the sharing of manufacturing capability, resource requirements, operation and maintenance, and product promotion using remote cloud computing. The main goal of cloud based approach is to provide platform for knowledge sharing with layering approach throughout design, manufacturing and integration of system process [36–41]. According to [42], a common knowledge sharing of data and system process, often involves hidden inter dependencies that are crucial for the manufacturing process. Hence, the data collected is required to be analysed and used for improving the manufacturing process [35].

2.6 Ontology Based Context Modeling

Industry manufacturing automation process consists of three vital components namely sensors, interconnected computing devices and industry assets. The objective of industry automation was (1) to validate the internal processing state of the industry and (2) user should be able to interact effectively with various industry components. However, according to Industry 4.0 revolution, these vital components are interconnected through Internet of Things (IoT) and Internet protocol across the globe. Hence, the objectives of such enhanced concept are (1) to provide context aware execution of industry process (2) to generate value-added information (3) to improve the monitoring and maintenance of various functions (4) to improve the performance of the industry manufacturing process in terms of cost and time. For this purpose, the ontology-based knowledge representation of the manufacturing process is preferred. In this, the way that various components and machine interact among each other are defined systematically. However, the sensed data from IoT based devices are imperfect and varied from device to device. Hence, the manufacturing context model has to account the dynamic nature of data obtained from various tools, products and machinery parts. In addition, the important and useful information relevant to the monitoring and planning of various manufacturing process need to be performed. In a way the characteristics of data in context model has to capture and exhibit the changes as well as heterogeneity in data. For this purpose, several research works exist in literature towards context modeling based on ontology for Industry manufacturing process. The authors in [43–47] discussed the role of ontology through formal and conceptualization that exhibits explicit way of specification and shared mode of various manufacturing processes. Basically, the ontology model consists of primitives such as axioms, instance, relations and concepts. A specific context aware knowledge base is created using these four primitives.

In ontology, Descriptive Logic Systems (DLS) are used for formalization and structuring knowledge representation and reasoning. In this account the ontology-based context modeling must concern about the specific domain within the industry concept. Hence, there should exist descriptive knowledge about every entity within the industry. The

Table 2 List of ontology based context aware modelling architectures for manufacturing process

CoBrA-ONT	Context Broker Architecture	Aitken and Chen [43]
SOUPA	Standard Ontology for Ubiquitous and Pervasive Applications	Finin et al. [44]
CON-ON	Context Ontology	Wang et al. [45]
MASON	Manufacturing Semantics Ontology	Lemaniganen et al. [46]
ADACOR		Borgo and Loitao [47]

examples of such entities include sensors devices, connecting nodes, customers etc. Both the dynamic knowledge as well static knowledge about the activities need to be collected as data for further analysis and knowledge generation [48–52]. Similarly, the temporal and spatial information play crucial role. Along with this, the spatiotemporal relationships among different activates must also be defined. The Ontology based context modeling that are discussed in literature are depicted in Table 2.

3 Simulation Based Optimization

In computer simulation modelling, simulation-based optimization is a decision-making tool for identifying an optimal design of a system. Here optimal design means a smart system with sensing, computing and control capabilities and improved efficiency [53]. As compared to testing the physical prototype, computer-based simulation provides much cheaper, faster and lesser time-and resource-consuming solutions [54]. In an example,

Basic Optimization Problem In optimization, a performance function $F = f(x_1, x_2, x_3, \ldots, x_n)$, consisting of $n -$ parameters, is derived and evaluated. This evaluation is performed by varying the variables : $x_1, x_2, x_3, \ldots, x_n$. These variables can be dependent or independent. Further, F is a scalar quantity and it can be assumed in various forms. For example, let us assume that F is a function to measure cost of a product in an organisation. There could be various parameters that can influence cost of a product like: material used in manufacturing, labour cost, electricity consumed, cost of transportation in collecting raw material etc. [55, 56]. In another example, let us assume that F is a function to measure the difference between actual and ideal throughput of a network. In this case, number of nodes, availability of connections among nodes, data transmission rate etc. influences the computations. Optimization problem can be expressed in two forms:

Minimize Optimization Problem (or Minimum of Objective Function) According to this problem**,** variables (i.e. $x_1, x_2, x_3, \ldots, x_n$) are adjusted in a manner to get minimum F scalar quantity. This quantity is also known as the objective or cost function. In order to represent a large number of variables in this computation, a transpose of a column vector is used in following form:

$$x^T = [x_1, x_2, \ldots, x_n] \tag{1}$$

Further, minimize optimization problem in n-dimensional Euclidean space (E^n) become minimize $F = f(x)$, *where* $x \in E^n$.

Maximum Optimization Problem (or Maximum of Objective Function) In this problem, maximum of F is obtained by computing the minimum of the negative of F followed by changing the sign of calculations i.e. $\max[f(x)] = -\min[-f(x)]$.

In both forms of optimization problems, various algorithms are available to achieve the objective function. These algorithms follow the following common steps of execution:

Algorithm 1 explains the common sequence of steps used by an optimization algorithm [57]. These steps are divided into four phases: initialisation, computations, convergence checking and observing final outcome and stop. In *initialisation* phase, initial variable value is selected and applied for initial objective function calculations. In *computations* phase, change in variable value is observed followed by calculating next variable value to be used for objective function calculation. After computing new objective function value, a change in objective function value is computed for analysis. In *convergence checking* phase, change in variable and objective function values are analysed. If these values lie within threshold limits then current value of variable and objective function is considered to be final outcome of optimization algorithm.

Algorithm 1 Optimization Algorithm Common Sequential Steps of Execution

Goal: Obtain the necessary convergence and identify the values x' and F' provided that the objective function gives optimum solution.

Premises: Let i is the variable, x_0 and F_0 store the initial values of variable and objective function, $f(x_j)$ is the computational function applied over *jth* variable, Δx_i^T is the column vector used to compute the changes in *ith* variable, $\varepsilon^F_{expected}$ and $\varepsilon^x_{expected}$ represent the maximum value of convergence expected in objective function and variable computations respectively.

Phase 1: Initialization

A. Initialise $i = 0$ and starting value of variable to x_0.
B. Compute initial value of objective function i.e. $F_0 = f(x_0)$.

Phase 2: Computations

A. Increment $i = i + 1$.
B. Compute the changes in x_i as: $\Delta x_i^T = [\Delta x_1 \Delta x_2 \ldots \Delta x_n]$.
C. Compute the next variable as: $x_i = x_{i-1} + \Delta x_i$.
D. Compute the objective function as: $F_i = f(x_i)$.
E. Compute the change in objective function as: $\Delta F_i = F_{i-1} - F_i$.

Phase 3: Convergence checking

A. If $\Delta F_i \leq \varepsilon^F_{expected}$ and/or $\Delta x_i \leq \varepsilon^x_{expected}$ then goto phase 4.
B. Else goto phase 2.

Phase 4: Observing final outcome and stopping execution

A. $x' = x_i$ and $F' = f(x')$.
B. Stop

Most of the non-linear simulation optimization algorithms are classified as: constrained and unconstrained algorithms. In constrained simulation optimization algorithms, constrained can be an equality or inequality form. For example, an objective function of achieving the desired throughput is acceptable when all nodes participated in the network communication, all links are used in these communications and required amount of information is transmitted to its destination nodes. This is an example of equality constrains and there are three equality constraints. Similar types of optimization problems are formalised as follows:

$$EQ_j(x) = 0, \text{Where } x \in E^n \text{and } i \in \{1, 2, \ldots, C_m\} \tag{2}$$

i.e. all constraints (start from $i = 1$ to $i = C_m$) in the equality constraint checking ($EQ_j(x)$) must be satisfied before considering that the objective of problem is achieved or problem is solved. Like equality constraint form, in equality constraint form impose various inequity constraints over variable or parameters for ensuring desired problem. For example, an objective function of achieving the desired throughput is acceptable when network traffic is distributed uniformly over all connected links and it does not go below or above the lower and upper threshold limits respectively, minimum number of packet queue length should be available to all sending and receiving nodes, and header length of each packet delivery should not exceed a certain minimum threshold limit. In this objective function, there are three inequality constrains. Similar types of optimization problems are formalised as follows:

$$IEQ_j(x) \leq or \geq 0, \text{Where } x \in E^n \text{and } i \in \{1, 2, \ldots, C_o\} \tag{3}$$

i.e. all constraints (start from $i = 1$ to $i = C_o$) in the inequality constraint checking ($IEQ_j(x)$) must be satisfied before considering that the objective of problem is achieved or problem is solved. All simulation optimization problems may add one or more equality of inequality constraints. Thus, these problems are considered in *constrained optimization problem*. Formally, it is defined as follows:

$$\text{minimize or maximize } F(x) \text{ Where } x \in E^n \tag{4}$$

$$EQ_j(x) = 0, \text{Where } x \in E^n \text{and } i \in \{1, 2, \ldots, C_m\} \tag{5}$$

$$IEQ_j(x) \leq or \geq 0, \text{Where } x \in E^n \text{and } i \in \{1, 2, \ldots, C_o\} \tag{6}$$

A simulation optimization problem is considered as unconstrained optimization problem if it does not add equality or inequality constraint. As it can be easily observed that constrained optimization is much difficult to achieve as compared to unconstrained optimization. Thus, a constrained optimization problem is analysed and changed to unconstrained optimization problem by redesigning and reformulating objective function in a manner that it should simultaneously satisfies all constraints. Let us discuss few IoT related case studies where there is use of constrained simulation optimization in problem designing and solution.

Case Study 1 Consider a network comprises of resource constrained wireless sensor and RFID integrated devices. The application of this network construction is to measure water quality in various water resources distributed across Dehradun geographical region, and give indications and suggestions to various water consumers (municipal corporation, industry sector, agriculture sector, forest department etc.) for use and reuse of water using systematic approaches. The objective of giving simulated optimized solution is to maintain the bandwidth consumption above certain threshold with minimum delay and maximum utilisation provided network may increase or decrease in volume. In order to achieve this objective, the cost of bandwidth utilisation is measured and appropriate controls are applied across the network to maintain the bandwidth above threshold using the minimum delay and maximum utilisation. This challenge is to be solved by formulating the problem as an optimization problem and propose the solution as well.

Let us formulate the problem statement using constrained simulation optimization and identify the solution. Let B_{ij} represents availability of bandwidth from ith source node to the jth destination node. All nodes in the network are assumed to be wireless sensor and RFID integrated. Now, suppose the cost per bit of utilising the bandwidth from ith source node to the jth destination node is P_{ij}. Thus, total cost ($P_{network}$) of network bandwidth utilisation is computed as:

$$P_{network} = \sum_{i=1}^{T_{SN}+T_{IN}+T_{DN}} \sum_{j=1}^{T_{SN}+T_{IN}+T_{DN}} P_{ij}B_{ij} \tag{7}$$

Here, T_{SN}, T_{IN} and T_{DN} represents the total number of source, intermediate and destination nodes available in the network respectively. Further, suppose T_{BS} is the total number of bandwidth sources (wired, wireless and both available for use and reuse), T_L is the total number of intermediate signal strengthen points (repeaters, extender, adapter, booster) and T_{UD} is the total number of users and devices available in the network for bandwidth consumption. Finally, constrained applied over the system is formalised as follows:

A. **Bandwidth Constraints**:

- *Maximum bandwidth per consumer constraint*: This constraint states that the maximum bandwidth consumed by jth consumer (user/device) using all ith bandwidth sources for data transfer between any source, and intermediate or destination node should be less than or equal to O_i.

$$\sum_{i=1}^{T_{BS}} B_{ij} \leq O_i, \text{Where}, j \in \{1, 2, \ldots, T_{UD}\} \tag{8}$$

- *Minimum bandwidth per consumer constraint*: This constraint states that the minimum bandwidth available for jth consumer (user/device) using all ith bandwidth sources for data transfer between any source, and intermediate or destination node should be greater than or equal to Q_i.

$$\sum_{i=1}^{T_{BS}} B_{ij} \geq Q_i, \text{Where}, j \in \{1, 2, \ldots, T_{UD}\} \tag{9}$$

- *Maximum bandwidth per connection constraint:* This constraint states that the maximum bandwidth available between ith source, and jth destination or intermediate node for all consumers should not exceed R_i.

$$\sum_{i=1}^{T_{SN}} B_{ij} \leq R_i, \text{Where}, j \in \{1, 2, \ldots, T_{IN} + T_{DN}\} \tag{10}$$

- *Minimum bandwidth per connection constraint*: This constraint states that the minimum bandwidth available between ith source, and jth destination or intermediate node for all consumers should be greater than or equal to S_i.

$$\sum_{i=1}^{T_{SN}} B_{ij} \geq S_i, \text{Where}, j \in \{1, 2, \ldots, T_{IN} + T_{DN}\} \tag{11}$$

B. **Bandwidth-Delay Constraints**:

With incorporation of delay measurement in efficient bandwidth utilisation, one of the possible solution, to solve the problem, is to reformulate Eq. (7) in quadratic form as:

$$\text{Minimize } P_{network} = \sum_{i=1}^{T_{SN}+T_{IN}+T_{DN}} \sum_{j=1}^{T_{SN}+T_{IN}+T_{DN}} \times \frac{1}{2}(B_{ij})^T H(B_{ij}) + (B_{ij})^T P_{ij} \tag{12}$$

Or

$$\text{Minimize } P_{network} = \sum_{i=1}^{T_{SN}+T_{IN}+T_{DN}} \sum_{j=1}^{T_{SN}+T_{IN}+T_{DN}} (B_{ij})^T D(B_{ij}) + (B_{ij})^T P_{ij} \tag{13}$$

Where,

$B_{ij} = (B_{11}, B_{12}, B_{13}, \ldots, B_{((T_{SN}+T_{IN}+T_{DN})-1)(T_{SN}+T_{IN}+T_{DN})})$

A symmetric matrix H called Hessian is computed as:

$$\begin{bmatrix} h_{11} & h_{12} & \ldots & h_{1(T_{SN}+T_{IN}+T_{DN})} \\ h_{21}h_{22} & & \ldots & h_{2(T_{SN}+T_{IN}+T_{DN})} \\ & & \ldots & \\ h_{(T_{SN}+T_{IN}+T_{DN})1} & h_{2(T_{SN}+T_{IN}+T_{DN})2} & \ldots & h_{(T_{SN}+T_{IN}+T_{DN})(T_{SN}+T_{IN}+T_{DN})} \end{bmatrix}$$

Upper triangular matrix D is computed from H as:

$$\begin{bmatrix} d_{11} & d_{12} & \ldots & d_{1(T_{SN}+T_{IN}+T_{DN})} \\ 0 & d_{22} & \ldots & d_{2(T_{SN}+T_{IN}+T_{DN})} \\ & & \ldots & \\ 0\,0\ldots d_{(T_{SN}+T_{IN}+T_{DN})(T_{SN}+T_{IN}+T_{DN})} \end{bmatrix} = \begin{bmatrix} 2h_{11} & h_{12} & \ldots & h_{1(T_{SN}+T_{IN}+T_{DN})} \\ 0 & 2h_{22} & \ldots & h_{2(T_{SN}+T_{IN}+T_{DN})} \\ & & \ldots & \\ 0\,0\ldots 2h_{(T_{SN}+T_{IN}+T_{DN})(T_{SN}+T_{IN}+T_{DN})} \end{bmatrix}$$

Subject to following bandwidth-delay product (BDP) constraints:

- *Maximum BDP per connection constraint*: This constraint states that the maximum BDP that can occur in the network should be less than or equal to T_i.

$$\sum_{i=1}^{T_{SN}} RTT_{ij} B_{ij} \leq T_i, \text{Where}, j \in \{1, 2, \ldots, T_{DN}\} \quad (14)$$

Here, RTT_{ij} is the round trip time between ith node and jth node. In addition, BDP calculations are acceptable if throughput between ith node and jth node is lesser than the ratio of transmission protocol's buffer size and round trip time, and transmission protocol's window size is greater than bandwidth and round trip time product. These conditions are applicable to Eqs. (15), (16) and (17) as well.

- *Minimum BDP per connection constraint*: This constraint states that the minimum delay that can occur between ith node and jth node should be greater than or equal to U_i.

$$\sum_{i=1}^{T_{SN}} RTT_{ij} B_{ij} \geq U_i, \text{Where}, j \in \{1, 2, \ldots, T_{DN}\} \quad (15)$$

- *Maximum BDP per network constraint*: This constraint states that the maximum BDP that can occur in the network should be less than or equal to V_{network}.

$$RTT_{network} \left(B_{ij}\right)^T \leq V_{network} \quad (16)$$

$$RTT_{network} = \begin{bmatrix} RTT_{11} & RTT_{12} & \ldots & RTT_{1(T_{SN}+T_{IN}+T_{DN})} \\ & RTT_{21} RTT_{22} & \ldots & RTT_{2(T_{SN}+T_{IN}+T_{DN})} \\ & & \ldots & \\ RTT_{(T_{SN}+T_{IN}+T_{DN})1} & RTT_{2(T_{SN}+T_{IN}+T_{DN})2} \ldots & RTT_{(T_{SN}+T_{IN}+T_{DN})(T_{SN}+T_{IN}+T_{DN})} \end{bmatrix}$$

- *Minimum BDP per network constraint*: This constraint states that the maximum BDP that can occur in the network should be greater than or equal to W_{network}.

$$RTT_{network} \left(B_{ij}\right)^T \geq W_{network} \quad (17)$$

C. **Inflow and outflow constraints**:

In order to incorporate inflow and outflow constraints, objective function in Eq. (13) can be extended as:

$$\text{Minimize } P_{network} = \sum_{i=1}^{T_{SN}+T_{IN}+T_{DN}} \sum_{j=1}^{T_{SN}+T_{IN}+T_{DN}} \left(B_{ij}^{io}\right)^T D \left(B_{ij}^{io}\right) + \left(B_{ij}^{io}\right)^T P_{ij} \quad (18)$$

Where, $B_{ij}^{io} = (B_{11}, B_{12}, B_{13}, \ldots, B_{(T_{SN}+T_{IN}+T_{DN})-1)(T_{SN}+T_{IN}+T_{DN})}, B_{11}^{io}, B_{12}^{io}, B_{13}^{io}, \ldots, B^{io}_{(T_{SN}+T_{IN}+T_{DN})-1)(T_{SN}+T_{IN}+T_{DN})})$

This objective function is acceptable subject to various inflow and outflow constraints. In order to derive these constraints, consider the network as directed graph $G = (X, Y)$, Where $X = (T_{SN} + T_{IN} + T_{DN}) \cup \{T_{sink}\}$ represents the total nodes along with a special sink node T_{sink} and Y represents the set of edges connecting these nodes. Let Z_i represents the energy capacity of ith node and z_{ij} represents the energy cost of receiving the packet and forwarding it from ith node to jth node.

- Minimum and maximum inflow rate per node: This constraint states that the maximum and minimum inflow per node that can occur between ith node and jth node should lies between Z_i^1 to Z_i^2.

$$Z_i^1 \leq \sum_{i=1}^{T_{SN}+T_{IN}+T_{DN}} \sum_{j=1}^{T_{SN}+T_{IN}+T_{DN}} \left(B_{ij}^i\right)^T D \left(B_{ij}^i\right) + \left(B_{ij}^i\right)^T P_{ij} \geq Z_i^2, \quad \text{Where}, j \in \{1, 2, \ldots, X\} \quad (19)$$

Where, $B_{ij}^i = \left(B_{11}, B_{12}, B_{13}, \ldots, B_{(T_{SN}+T_{IN}+T_{DN})-1)(T_{SN}+T_{IN}+T_{DN})}, B_{11}^i, B_{12}^i, B_{13}^i, \ldots, B^i_{(T_{SN}+T_{IN}+T_{DN})-1)(T_{SN}+T_{IN}+T_{DN})}\right)$

- Minimum and maximum outflow rate per node: This constraint states that the maximum and minimum inflow per node that can occur between ith node and jth node should lies between Z_i^3 to Z_i^4.

$$Z_i^3 \le \sum_{i=1}^{T_{SN}+T_{IN}+T_{DN}} \sum_{j=1}^{T_{SN}+T_{IN}+T_{DN}} \left(B_{ij}^o\right)^T D\left(B_{ij}^o\right) + \left(B_{ij}^o\right)^T P_{ij} \ge Z_i^4,$$
$$\text{Where, } j \in \{1,2,\ldots,X\} \tag{20}$$

Where, $B_{ij}^i = \Big(B_{11}, B_{12}, B_{13}, \ldots, B_{(T_{SN}+T_{IN}+T_{DN})-1)(T_{SN}+T_{IN}+T_{DN})},$
$B_{11}^o, B_{12}^o, B_{13}^o, \ldots, B^o_{(T_{SN}+T_{IN}+T_{DN})-1)(T_{SN}+T_{IN}+T_{DN})}\Big)$

- Minimum inflow and outflow rate per edge: This constraint states that the maximum and minimum inflow per node that can occur between ith node and jth node should lies between Z_i^1 to Z_i^2.

$$Z_i^{e1} \le \sum_{i=1}^{T_{SN}+T_{IN}+T_{DN}} \sum_{j=1}^{T_{SN}+T_{IN}+T_{DN}} \left(B_{ij}^{io}\right)^T D\left(B_{ij}^{io}\right) + \left(B_{ij}^{io}\right)^T P_{ij} \ge Z_i^{e2},$$
$$\text{Where, } j \in \{1,2,\ldots,X\} \tag{21}$$

Where, $B_{ij}^i = \big(B_{11}, B_{12}, B_{13}, \ldots, B_{(T_{SN}+T_{IN}+T_{DN})-1)(T_{SN}+T_{IN}+T_{DN})},$ $B_{11}^{io}, B_{12}^{io}, B_{13}^{io}, \ldots, B^{io}_{(T_{SN}+T_{IN}+T_{DN})-1)(T_{SN}+T_{IN}+T_{DN})}\big)$

This is brief formulation of any simulation model. Solution to simulation optimisation problem can be analysed using simulation optimization methods. In next section, a simulation example is taken for experimentation and analysis.

3.1 Simulation Optimization Method

Most of the existing specialized networks consist of a number of network monitoring stations arranged in serial or complex non-serial configurations. Thus, multi-stage monitoring is an important design aspect in network construction. In serial and multi-stage monitoring, QoS parameters are ensured the network performance is consistent through the network and as per specifications. Whereas, complex non-serial configuration designs deal with measuring the optimal level of QoS parameters at different points. In both scenarios, some of the important issues to be considered include: (a) should each QoS parameter need to be evaluated and inspected at all or particular monitoring stage?, (b) If answer to (a) is 'yes' then 100% monitoring is required else there is need to identify the optimal number of QoS parameters and acceptable number of monitoring, and (c) in non-serial and complex scenarios. Optimum number of QoS parameters are evaluated from local optimum solutions suitable for different scenarios. In this section, two heuristic algorithms are proposed for identifying local optimum solutions. Algorithm 1 is extended form of tabu [58, 59] algorithm in finding local optimum value for QoS parameters. Algorithm 2 is extended form of ant-Inspired heuristic algorithm for QoS parameters in Small Scale IoT. Further, this algorithm finds local optimum value for QoS parameter.

Algorithm 1 Tabu Search Algorithm for QoS Parameters in Small Scale IoT

Premises: Let Q_0 is the initial candidate solution for QoS parameter, L_{max} is the maximum length of list containing values of QoS parameters to be analyzed, $Q_{desired}$ is the desired QoS parameter value.

Goal: To identify local optimum values for QoS parameters

Step 1:- Initialize local optimum value for QoS parameters i.e. $Q = Q_{local\_optimum}$.

Step 2:- Construct a list to record different values for QoS parameters i.e. $L = \{\}$.

Step 3:- Set the maximum tabu list length i.e. length $(L) = L_{max}$.

Step 4:- While $Q_{local\_optimum} \neq Q_{desired}$:

Step 4a:- Select a neighboring point (R_i) for measuring QoS parameter

Step 4b:- If $R_i \in L$ then

Step 4c:- If length(L) $> L_{max}$ then

Step 4d:- Remove oldest solution from L

Step 4e:- Append R_i to L

Step 4f:- End If

Step 4g:- End If

Step 4h:- If QoS parameter (Q_i) measured at ith random point R_i is lesser than previous local optimum value i. e. $Q_i < Q_{local\_optimum}$ then

Step 4i:- $Q_{local\_optimum} = Q_i$

Step 5:- return $Q_{local\_optimum}$

Algorithm 2 Ant-Inspired Heuristic Algorithm for QoS Parameters in Small Scale IoT

Goal: To identify local optimum values for QoS parameters

Input: A set of point in Small Scale IoT network for QoS parameter evaluation

Output: A set of points having almost similar local optimum values for QoS parameters

Step 1:- While all points are not scanned**:**

Step 2:- f ant is unloaded **then**

Step 3:- Pick QoS checkpoint and consider it in attended list

Step 4:- End If

Step 5:- Else If ant is loaded and it finds a checkpoint having similar QoS performance as compared to currently loaded checkpoint **then**

Step 6:- Appended the loaded checkpoint in newly find similar QoS checkpoint

Step 7:- Else If ant is loaded and it does not find a checkpoint having similar QoS performance as compared to currently loaded checkpoint **then**

Step 8:- Formulate a new category of checkpoint and append loaded checkpoint in this category

Step 9:- End While

Step 10:- While all categories are not scanned**:**

Step 11:- Pick one category at a time

Step 12:- Randomly select one checkpoint from this category

Step 13: Ant's agent load a checkpoint and compared its QoS performance with randomly selected checkpoint

Step 14:- While Ant does not execute all its agent in current category

Step 15:- If currently loaded checkpoint is local optimum solution **then**

Step 16:- Save it in Ant's memory

Step 17:- Else

Step 18:- Mark this checkpoint as attended and unload it

Step 19:- Pick another checkpoint in this category

Step 20:- End While

Step 21:- End While

Step 22:- If each ant's agent bring new change in optimum solution **then**

Step 23:- Change the local optimum value

Step 24:- Else

Step 25:- Consider the local optimum value as threshold value of QoS parameter

3.2 Simulation Optimization Applications

Simulation optimization methods with single or multiple objectives are applicable to various fields. These fields require the optimization of variables with multiple criteria and specified objectives. Few examples of simulation optimization applications are as follows:

- *Inventory and production systems*: Ye and You [60] used simulation-optimization method in designing an efficient framework for reducing the total operation cost in an inventory system using kriging model. This model is applied region-wise and found to be reducing the optimization computational time. Further, it is found that the proposed approach solve supply chain problems through four features: multi-sourcing capability, asynchronous ordering, uncertain demand and stochastic lead time. In order to validate this model, a network of 18 nodes is constructed and inventory management capabilities are integrated. After this construction, model is analysed from two major perspective with objective of smooth system working and reduced operational cost. Jalali and Nieuwenhuyse [61] conducted a survey in which simulation optimization has been used for large scale complicated and mathematically intractable practical problems in inventory systems. In one observation, it is found that metaheuristics approaches focusing on genetic algorithms with stochastic constraints are widely acceptable in literature. Whereas, analysing several simulation optimization techniques and their applicability to one set of problems in inventory management system is also popular in practical implementation and research. Chu et al. [62] Chu et al. has proposed another simulation optimization-based framework for real-world multi-echelon inventory systems which are mathematically challenging to solve. This model shows its novelty in implementing simulation optimization over distributed system with an objective of minimizing the inventory costs. An agent-based system uses Monte-Carlo methods for validating the objective function followed by cutting plane algorithm in finding the local optimal solution. Two case studies are taken in demonstrating the proposed framework approach and its outcomes.
- *Building designs and models*: Chen et al. [63] has conducted a detailed survey over simulation-based approaches and identifying the research gaps in design of building and their performance in terms of energy and indoor environmental features. In initial design optimization approach, simulation experiments are conducted using mixed-mode ventilation and lighting dimming control algorithms with an objective of designing a local green building and its assessment. A non-dominated sorting genetic algorithm (NSGA-II) is subsequently integrated with modelling experiments which in-turn helps in finding optimum solution without accepting the optimization outcome below any dangerous level. This study is helpful in designing green buildings with objective of energy-saving capabilities.

3.3 Efficiency and Improvement in the Quality of Production

Efficiency and improvement in quality of production can be achieved using various methods. In this work, Ranking and scaling based simulation optimization algorithm is applied over network scenarios for identifying local optimum values for QoS parameters. These local optimum solutions are helpful in increasing the network performance and its efficiency. Simulation annealing based optimized algorithms provides comparative analysis of consecutive values in identifying local and global optimum solutions for a performance parameter or within specific range of parameter's value. Further, two QoS parameters (throughput and transit delay) are evaluated for different scenarios.

Algorithm 3 Simulation Annealing Enabled Ranking and Scaling Statistical Simulation Constrained Optimization Algorithm

Step 1: ***Initialization***—Randomly pick an observational point for QoS analysis. Additionally, all agents are activated to start collecting data for picked observational point.

Step 2: ***Count the observational points***—In order to find local optimum value, identify a set of duration during which observations will be recorded.

Step 3: ***Calculate local optimum value***—During first execution, observational value is considered as local optimum value whereas every subsequent value is compared with current value for finding the most appropriate result.

Step 4: ***Select a range for finding local optimum value***—Local optimum value is identified from range of nearby evaluating points. This range is decided based on change in local optimum value i.e. if local optimum value is not changing for a long period of time then range if period between previous cut-off and current value.

Step 5: ***Update local optimum and its calculating range values***—Local optimum score values and their ranges for calculation are updated regularly because performance of any observing and monitoring point changes over time. This change happens because of various reasons like: hardware performance, increase in data sending and receiving units, side channel attacks etc.

Step 6: ***Repeat***—The process of identifying local optimum value and their ranges is a continuous process. Lifetime of these activities varies from first communication to last communication of any type in the network.

4 Conclusion

This chapter addressed the need for modeling and simulation in Industry4.0. First, RAMI4.0 stands for Reference Architecture Model for Industry 4.0 was discussed. The RAMI4.0 provides 3D mapping reference as solution to various Industry4.0 concept. Next, the chapter discussed about the SysML as modeling language. The SysML objective is to provide detailed information and analysis of Industry 4.0 concepts. Further, the chapter discussed the production flow scheme (PFS) model for the discrete event systems (DES). Basically, PFS is a graph-based process interpretation using Petri Net (PN). Then, business process models (BPM) was present that provide basic behavioral notions of the various functional elements of the Industry 4.0 systems. As the manufacturing industry system converge with cyber, cyber physical system, and human experts. It is essential for provide knowledge-based presentation of various industrial systems. The chapter discusses the UML based design for manufacturing systems. Finally, ontology based Descriptive logic systems were discussed as solution for formalization and structuring the knowledge representation. The later part of the chapter discussed the simulation modelling, simulation-based optimization is a decision-making tool for identifying an optimal design of a system.

References

1. Edward A. Lee, "The Past Present and Future of Cyber-Physical Systems: A Focus on Models", Sensors 2015, 15, 4837-4869;
2. Internet Protocol for Smart Objects (IPSO) Alliance, IPSO Smart Object Committee, IPSO SmartObject Guideline, Smart ObjectsExpansion Pack, 27 October, 2015.
3. Wortmann, Andreas, Benoit Combemale, and Olivier Barais. "A systematic mapping study on modeling for industry 4.0." In 2017 ACM/IEEE 20th International Conference on Model Driven Engineering Languages and Systems (MODELS), pp. 281-291. IEEE, 2017.
4. Vogel-Heuser, Birgit, and Dieter Hess. "Guest editorial industry 4.0–prerequisites and visions." IEEE Transactions on Automation Science and Engineering 13, no. 2 (2016): 411-413.
5. Nayyar, A., & Puri, V. (2017). Comprehensive Analysis & Performance Comparison of Clustering Algorithms for Big Data. *Review of Computer Engineering Research*, *4*(2), 54-80.
6. Cockburn, Alistair. Writing effective use cases. Addison-Wesley Professional, 2000.
7. Kagermann, H., W. Wahlster and J. Helbig "Recommendations for implementing the strategic initiative Industrie 4.0" Final report of theIndustrie 4.0 Working Group, 2013.
8. Bortolini, Marco, Emilio Ferrari, Mauro Gamberi, Francesco Pilati, and Maurizio Faccio. "Assembly system design in the Industry 4.0 era: a general framework." IFAC-PapersOnLine 50, no. 1 (2017): 5700-5705.
9. Jay Lee, BehradBagheri, Hung-An Kao, "A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems", Manufacturing Letters 3 (2015) 18–23.
10. Martin Bonev, Lars Hvam, John Clarkson, Anja Maier, Computers in Industry, Computers in Industry 74 (2015) 58–70
11. L. Wang, M. Törngren, M. Onori, "Current status and advancement of cyber-physical systems in manufacturing", Journal of Manufacturing Systems, Volume 37, Part 2, October 2015, Pages 517–527.
12. Zhuming Bi, Li Da Xu, and Chengen Wang, "Internet of Things for Enterprise Systems of Modern Manufacturing" IEEE Transactions on industrial informatics, vol. 10, no. 2, May 2014.
13. K. Thramboulidis, "A Cyber-Physical System-based Approach for Industrial Automation Systems", Computers in Industry, Volume 72, September 2015, Pages 92–102.
14. Solanki, A., & Nayyar, A. (2019). Green Internet of Things (G-IoT): ICT Technologies, Principles, Applications, Projects, and Challenges. In *Handbook of Research on Big Data and the IoT* (pp. 379-405). IGI Global.
15. Nayyar, A., Puri, V., & Le, D. N. (2017). Internet of nano things (IoNT): Next evolutionary step in nanotechnology. *Nanoscience and Nanotechnology*, *7*(1), 4-8.
16. Nayyar, A., Jain, R., Mahapatra, B., & Singh, A. (2019). Cyber Security Challenges for Smart Cities. In Driving the Development, Management, and Sustainability of Cognitive Cities (pp. 27-54). IGI Global.
17. Das, S., & Nayyar, A. (2019). Innovative Ideas to Manage Urban Traffic Congestion in Cognitive Cities. In *Driving the Development, Management, and Sustainability of Cognitive Cities* (pp. 139-162). IGI Global.

18. Batth, R. S., Nayyar, A., & Nagpal, A. (2018, August). Internet of Robotic Things: Driving Intelligent Robotics of Future-Concept, Architecture, Applications and Technologies. In *2018 4th International Conference on Computing Sciences (ICCS)*(pp. 151-160). IEEE.
19. Solaimani, S., & Bouwman, H. (2012). A framework for the alignment of business model and business processes. Business Process Management Journal, 18(4), 655-679.
20. Zott, C., Amit, R., & Massa, L. (2011). The Business Model: Recent Developments and Future Research. Journal of management, 37(4), 1019-1042.
21. Heikkilä, J., Tyrväinen, P., & Heikkilä, M. (2010). Designing for performance - a technique for business model estimation. Proceedings of EBRF 2010, Research Forum to Understand Business in Knowledge Society, 1-15.
22. P. Leitao, A. W. Colombo and F. J. Restivo, "ADACOR: a collaborative production automation and control architecture," in IEEE Intelligent Systems, vol. 20, no. 1, pp. 58-66, Jan.-Feb. 2005.
23. C. T. Sungur, U. Breitenbücher, F. Leymann, and M. Wieland, "Context sensitive adaptive production processes," Procedia CIRP, vol. 41, pp. 147–152, 2016.
24. O. Harcuba and P. Vrba, "Ontologies for flexible production systems," in Emerging Technologies & Factory Automation (ETFA), 2015 IEEE 20th Conference on. IEEE, 2015, pp. 1–8.
25. D. Holz, A. Topalidou-Kyniazopoulou, F. Rovida, M. R. Pedersen, V. Krüger, and S. Behnke, "A skill-based system for object perception and manipulation for automating kitting tasks," in Emerging Technologies & Factory Automation (ETFA), 2015 IEEE 20th Conference on. IEEE, 2015, pp. 1–9.
26. B. Vogel-Heuser, S. Rösch, J. Fischer, T. Simon, S. Ulewicz, J. Folmer et al., "Fault handling in PLC-based industry 4.0 automated production systems as a basis for restart and self-configuration and its evaluation," Journal of Software Engineering and Applications, vol. 9, no. 01, p. 1, 2016.
27. K. Alexopoulos, S. Makris, V. Xanthakis, K. Sipsas, and G. Chryssolouris, "A concept for context-aware computing in manufacturing: the white goods case," International Journal of Computer Integrated Manufacturing, vol. 29, no. 8, pp. 839–849, 2016.
28. E. Irisarri, M. V. García, F. Pérez, E. Estévez, and M. Marcos, "A modelbased approach for process monitoring in oil production industry," in Emerging Technologies and Factory Automation (ETFA), 2016 IEEE 21st International Conference on. IEEE, 2016, pp. 1–4.
29. H. Kern, F. Stefan, and V. Dimitrieski, "Intelligent and self-adapting integration between machines and information systems," IADIS International Journal on Computer Science & Information Systems, vol. 10, no. 1, 2015.
30. D. Chen, A. Maffei, J. Ferreirar, H. Akillioglu, M. R. Khabazzi, and X. Zhang, "A virtual environment for the management and development of cyber-physical manufacturing systems," IFAC-PapersOnLine, vol. 48, no. 7, pp. 29–36, 2015.
31. D. Chen, D. V. Panfilenko, M. R. Khabbazi, and D. Sonntag, "A modelbased approach to qualified process automation for anomaly detection and treatment," in Emerging Technologies and Factory Automation (ETFA), 2016 IEEE 21st International Conference on. IEEE, 2016, pp. 1–8.
32. O. Kovalenko, M. Wimmer, M. Sabou, A. Lüder, F. J. Ekaputra, and S. Biffl, "Modeling AutomationML: Semantic web technologies vs. model-driven engineering," in Emerging Technologies & Factory Automation (ETFA), 2015 IEEE 20th Conference on. IEEE, 2015, pp.1–4.
33. Thoben, Klaus-Dieter, Stefan Wiesner, and Thorsten Wuest. ""Industrie 4.0" and smart manufacturing-a review of research issues and application examples." International Journal of Automation Technology 11, no. 1 (2017): 4-16.
34. Chiu, Yu-Chen, Fan-Tien Cheng, and Hsien-Cheng Huang. "Developing a factory-wide intelligent predictive maintenance system based on Industry 4.0." Journal of the Chinese Institute of Engineers 40, no. 7 (2017): 562-571.
35. Dassisti, Michele, Herve Panetto, Mario Lezoche, Pasquale Merla, Concetta Semeraro, Antonio Giovannini, and Michela Chimienti. "Industry 4.0 paradigm: The viewpoint of the small and medium enterprises." In 7th International Conference on Information Society and Technology, ICIST 2017, vol. 1, pp. 50-54. 2017.
36. Singh, S. P., Nayyar, A., Kaur, H., & Singla, A. (2019). Dynamic Task Scheduling using Balanced VM Allocation Policy for Fog Computing Platforms. *Scalable Computing: Practice and Experience*, *20*(2), 433-456.
37. Kaur, A., Gupta, P., Singh, M., & Nayyar, A. (2019). Data Placement in Era of Cloud Computing: a Survey, Taxonomy and Open Research Issues. *Scalable Computing: Practice and Experience*, *20* (2), 377-398.
38. Singh, P., Gupta, P., Jyoti, K., & Nayyar, A. (2019). Research on Auto-Scaling of Web Applications in Cloud: Survey, Trends and Future Directions. *Scalable Computing: Practice and Experience*, *20*(2), 399-432.
39. Singh, S. P., Nayyar, A., Kumar, R., & Sharma, A. (2019). Fog computing: from architecture to edge computing and big data processing. *The Journal of Supercomputing*, *75*(4), 2070-2105.
40. Nayyar, A. (2011). INTEROPERABILITY OF CLOUD COMPUTING WITH WEB SERVICES. *International Journal of ElectroComputational World & Knowledge Interface*, *1*(1).
41. Nayyar, A. (2011). Private Virtual Infrastructure (PVI) Model for Cloud Computing. *International Journal of Software Engineering Research and Practices*, *1*(1), 10-14.
42. Seiger, Ronny, Christine Keller, Florian Niebling, and Thomas Schlegel. "Modelling complex and flexible processes for smart cyber-physical environments." Journal of Computational Science 10 (2015): 137-148.
43. Aitken S., Chen Y. (2008) COBrA and COBrA-CT: Ontology Engineering Tools. In: Burger A., Davidson D., Baldock R. (eds) Anatomy Ontologies for Bioinformatics. Computational Biology, vol 6. Springer, London
44. T. Finin and A. Joshi, "SOUPA: standard ontology for ubiquitous and pervasive applications," The First Annual International Conference on Mobile and Ubiquitous Systems: Networking and Services, 2004. MOBIQUITOUS 2004., Boston, MA, USA, 2004, pp. 258-267.
45. X. H. Wang, D. Q. Zhang, T. Gu and H. K. Pung, "Ontology based context modeling and reasoning using OWL," IEEE Annual Conference on Pervasive Computing and Communications Workshops, 2004. Proceedings of the Second, Orlando, FL, USA, 2004, pp. 18-22.
46. S. Lemaignan, A. Siadat, J. -. Dantan and A. Semenenko, "MASON: A Proposal For An Ontology Of Manufacturing Domain," IEEE Workshop on Distributed Intelligent Systems: Collective Intelligence and Its Applications (DIS'06), Prague, 2006, pp. 195-200.
47. Borgo S., Leitão P. (2007) Foundations for a Core Ontology of Manufacturing. In: Sharman R., Kishore R., Ramesh R. (eds) Ontologies. Integrated Series in Information Systems, vol 14. Springer, Boston, MA
48. D. Schubert, C. Heinzemann, and C. Gerking, "Towards Safe Execution of Reconfigurations in Cyber-Physical Systems," in Component-Based Software Engineering (CBSE), 2016 19th International ACM SIGSOFT Symposium on. IEEE, 2016, pp. 33–38.
49. C. T. Sungur, U. Breitenbücher, F. Leymann, and M. Wieland, "Context sensitive adaptive production processes," Procedia CIRP, vol. 41, pp.147–152, 2016.
50. T. Kosar, S. Bohra, and M. Mernik, "Domain-specific languages: A systematic mapping study," Information and Software Technology, vol. 71, pp. 77–91, 2016.
51. Q. Zhang, Y. Liu, and Z. Zhang, "A new method for automatic optimization of drawbead geometry in the sheet metal forming process based on an iterative learning control model," The

International Journal of Advanced Manufacturing Technology, pp. 1–17, 2016.
52. M. Lütjen, H.-J. Kreowski, M. Franke, K.-D. Thoben, and M. Freitag "Model-driven logistics engineering–challenges of model and object transformation," Procedia Technology, vol. 15, pp. 303–312, 2014.
53. Xu, J., Huang, E., Hsieh, L., Lee, L.H., Jia, Q.S. and Chen, C.H., 2016. Simulation optimization in the era of Industrial 4.0 and the Industrial Internet. Journal of Simulation, 10(4), pp. 310-320.
54. Inanlouganji, Alireza, Giulia Pedrielli, Georgios Fainekos, and Sebastian Pokutta. "Continuous simulation optimization with model mismatch using Gaussian process regression." In 2018 Winter Simulation Conference (WSC), pp. 2131-2142. IEEE, 2018.
55. Xu, J., Huang, E., Chen, C.H. and Lee, L.H., 2015. Simulation optimization: A review and exploration in the new era of cloud computing and big data. Asia-Pacific Journal of Operational Research, 32(03), p. 1550019.
56. Carson, Y. and Maria, A., 1997, December. Simulation optimization: methods and applications. In Proceedings of the 29th conference on Winter simulation (pp. 118-126). IEEE Computer Society.
57. Wusheng Lu, Andreas Antoniou, "Practical optimization algorithms and engineering applications", Springer, ISBN-10: 0-387-71106-6, 2007.
58. Tabu Search Algorithm: https://www.slideshare.net/afar1111/metaheuristics-techniques-1-30432226
59. Glover, F., 1986. Future paths for integer programming and links to artificial intelligence. Computers & operations research, 13(5), pp. 533-549.
60. Ye, W. and You, F., 2016. A computationally efficient simulation-based optimization method with region-wise surrogate modeling for stochastic inventory management of supply chains with general network structures. Computers & Chemical Engineering, 87, pp. 164-179.
61. Jalali, H. and Nieuwenhuyse, I.V., 2015. Simulation optimization in inventory replenishment: a classification. IIE Transactions, 47(11), pp. 1217-1235.
62. Chu, Y., You, F., Wassick, J.M. and Agarwal, A., 2015. Simulation-based optimization framework for multi-echelon inventory systems under uncertainty. Computers & Chemical Engineering, 73, pp. 1-16.
63. Chen, X., Yang, H. and Zhang, W., 2018. Simulation-based approach to optimize passively designed buildings: a case study on a typical architectural form in hot and humid climates. Renewable and Sustainable Energy Reviews, 82, pp. 1712-1725.\

K. Rajalakshmi is an Assistant Professor in Department of Computer Science and Engineering, Jaypee Institute of Information Technology, Noida, India. Dr. Rajalakshmi has completed her Ph.D. (Computer Science and Engineering) in 2016 at Department of computer science and engineering, JIIT, Noida, Indian. Dr. Rajalakshmi has published several research papers in reputed International Journals and Conferences, published book chapters in CRC Press, Springer, IET and IGI global. Dr. Rajalakshmi is guest editor of International Journal Recent Patents on Engineering (Bentham Science). Dr. Rajalakshmi is technical program committee member and reviewer in several International Conferences. She is professional member in IEEE, ACM and CSI.

Adarsh Kumar is working as an associate professor in the department of systemics, school of computer science, university of petroleum and energy studies (UPES), Dehradun, India. He completed his Post-doc from SRI, AIT, Ireland and actively participated in EU H2020 sponsored research project worth 4 billion euros. He is currently executing two research projects. He hold a Ph.D. degree in Computer Science Engineering and Information Technology (CSE&IT) from Jaypee Institute of Information Technology, Noida, India. The main focus of his research is related with cryptography primitives and protocols; lightweight cryptography, post-quantum cryptosystems, internet of things, mobile ad-hoc networks etc. He has the experience of working in two continents (ASIA and EUROPE) including countries like Ireland, united-kingdom, Czech republic, India etc. He has more than 11 years of teaching experience and multi-discipline ability in computer science and engineering subjects. For example, cryptograph and network security, internet of things, wireless and sensor networks, software engineering, object-oriented programming, data structures, analysis of algorithms, discrete mathematics, IT network security, security protocols and lightweight cryptography. He has more than 35 publications including reputed journals and conferences in his account. He held various positions in international conferences like: IC3, SNDS, NGCT, SUSCOM, SICS, UPCON etc. Presently, he is guest editor of special issue on "Lightweight Security Aspects in Resource Constrained Internet of Things (IoT) devices and networks" in journal "Recent Patents on Engineering", Bentham Science publishers.

Augmented Reality and Industry 4.0

Kruti Lavingia and Sudeep Tanwar

Abstract

Augmented Reality is widely emerging in almost every field whether it is entertainment (gaming), the field of visual art, photography, cinema, interactive digital media, healthcare or industry. This innovation is sprouting in a previous couple of years with a developing number of luxury and affordable AR gadgets getting to be accessible to the overall population. AR systems have exhibited the ability to advance undertaking productivity in an expansive scope of ventures. It is one of the most promising fields in the context of Industry 4.0. A number of researchers are working on this emerging technology as it is still a challenging area. This chapter discusses the basics of Augmented Reality, its history, types, working, applications and its emergence into the Industry 4.0.

Keywords

Augmented reality · Industry 4.0 · Virtual reality · Speech recognition · Marker-based · Marker-less · Holographic

1 Introduction

Industry 4.0 alludes to another modern innovation period that is changing current frameworks, sensors, machines and remaining tasks at hand. It can help make progressively productive procedures utilizing the nine pillars of innovation: Cybersecurity, AR, automated robot, system integration, simulation, big data, additive manufacturing, distributed computing, and the IoT [1, 2]. Amongst the nine pillars of Industry 4.0 as depicted in Fig. 1, Augmented Reality is one of the most important pillars of Industry 4.0. Assuming an indispensable job in Industry 4.0, AR chooses to assemble parts and send mechanical flaw status data to applications introduced on clients' telephones. Numerous organizations are creating applications to give constant data about item preparing to specialists. They are additionally making brilliant applications that help with basic leadership and improved work systems [3].

K. Lavingia · S. Tanwar (✉)
Department of Computer Science and Engineering, Institute of Technology, Nirma University, Ahmedabad, India
e-mail: kruti.lavingia@nirmauni.ac.in; sudeep.tanwar@nirmauni.ac.in

1.1 Augmented Reality

Augmented reality is the development that expands our physical world, including layers of electronic information onto it [4, 5]. AR advancement passes on customers the chance to experience an augmented world by overlaying virtual information in reality. This is the manner by which the customer can be in contact with both the authentic and virtual world and get progressing data or estimations. As opposed to Virtual Reality (VR), AR does not make the whole fake conditions to override the genuine condition with a virtual one. AR appears in direct viewpoint on a present circumstance and incorporates sounds, chronicles, representations to it. A viewpoint on the physical genuine condition with superimposed PC made pictures, subsequently changing the impression of reality, is the AR.

The term itself was initiated in the year 1990, and the most essential business uses were in TV and military. With the climb of the Internet and PDAs, AR uncovered its second wave and nowadays is commonly related to the keen thought. 3D models are clearly foreseen onto physical things or merged ceaselessly, unique augmented reality applications influence our penchants, open movement, and news sources.

AR applications consistently partner modernized development to an unprecedented 'marker', or with the help of GPS in phones pinpoint the territory. Broadening is going on continuously and inside the setting of nature, for example, overlaying scores to a live feed game events. Until specific years back, the nonappearance of cost-moderate contraptions was the essential impediment to a wide determination of AR applications.

A. Nayyar, A. Kumar (eds.), *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*,
Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-14544-6_8

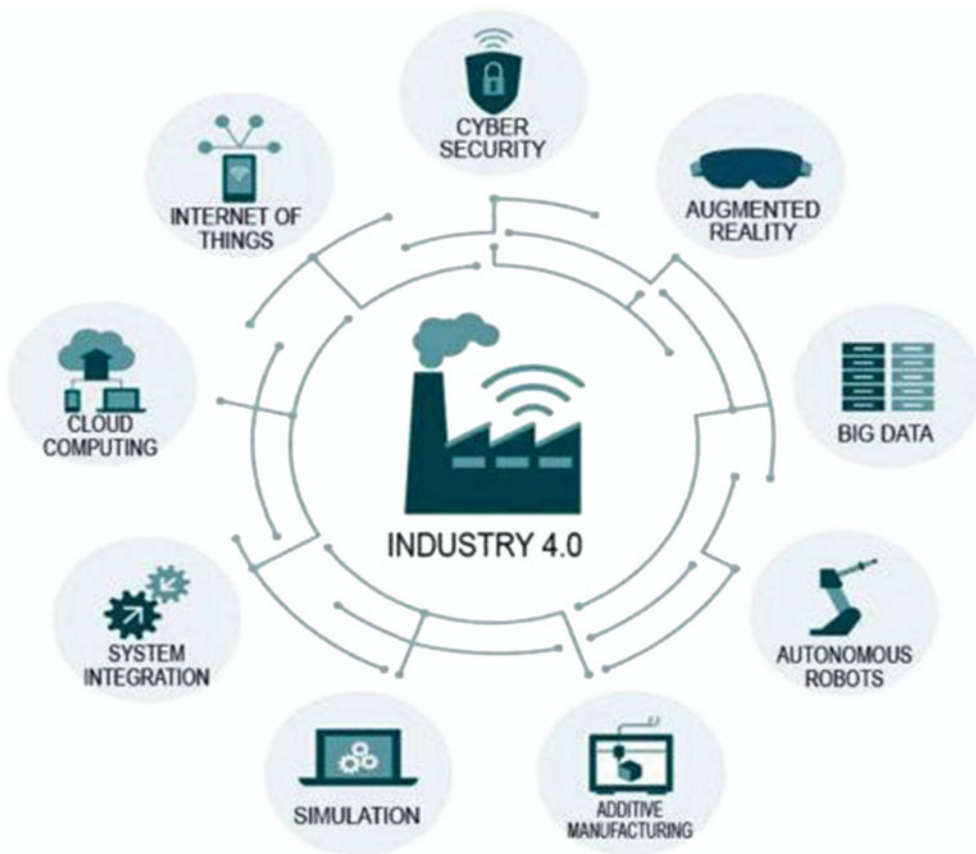


Fig. 1 Nine pillars of Industry 4.0 [3]

Nowadays, no matter how you look at it the determination of PDAs has emptied this containment, as mobile phones and tablets feature all of the sensors and planning units expected to make and send AR applications. Moreover, the advancement improvements that impact mobile phones can convey new testing things, conventionally suggested as wearables, and organizations are pushing ahead with new characterizations of AR contraptions, for instance, Emacula contact central focuses from Innovega, the Vuzix Blade 3000 AR glasses or the Meta 2 AR headset. The overall market for augmented reality is growing snappy and the unavoidable choice of AR headways proposes an irrefutable impact on the overall population.

1.2 Brief History of Augmented Reality

The author in [6] has summarized the rise of Augmented Reality starting from the 1960s. AR in the 1960 era: Ivan Sutherland and Bob Sproull, in the year 1968 made the first head-mounted feature, they thought of it as The Sword of Damocles. Clearly, it was a horrendous contraption that indicated rough PC structures.

AR in the 1970 era: Myron Krueger, in the year 1975 made Videoplace—a phony reality lab. The analyst proposed the relationship with cutting edge stuff by human improvements. This thought in the future was used for explicit projectors, camcorders, and onscreen diagrams.

AR in the 1980 era: Steve Mann, in the year 1980 established a first conservative PC called EyeTap, expected to be worn before our eye. It used to record the scene to superimposed ramifications for it later, and show everything to a customer who could similarly play with it by methods for head improvements. Douglas George and Robert Morris in the year 1987, established the model of a heads-up introduction (HUD). It demonstrated astronomical data above the certifiable sky.

AR in the 1990 era: 1990 indicated the presence of the “augmented reality” term. It recently appeared in the study made by Thomas Caudell and David Mizell—Boeing association researchers. Louis Rosenberg of the US Air Force in the year 1992 made the AR system called “Virtual Fixtures”. A social occasion of scientists driven by Frank Delgado and Mike Abernathy in the year 1999, attempted new course programming, which made streets and runways data from a helicopter video.

AR in the 2000 era: A Japanese analyst Hirokazu Kato, in the year 2000 made and conveyed ARToolKit—an open-source SDK. Later it was changed as per work with Adobe.

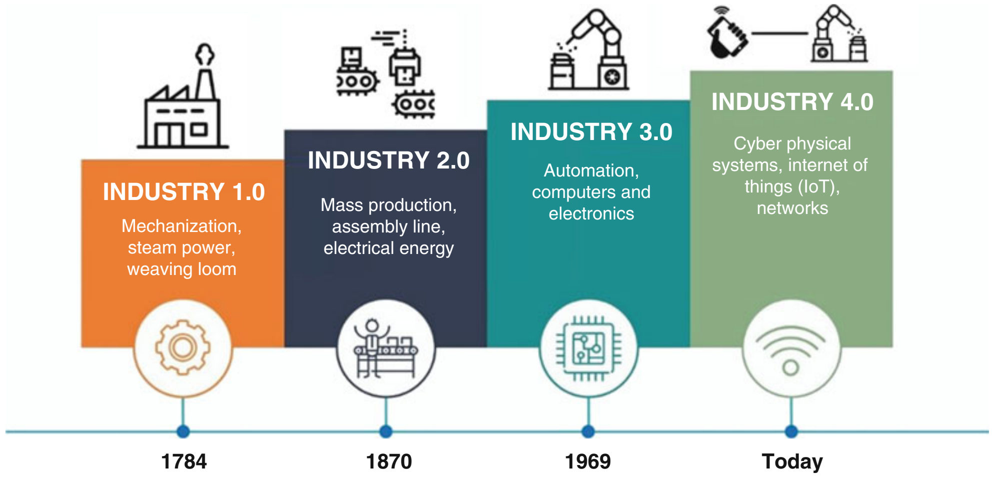


Fig. 2 The rise of Industry 4.0 [8]

Trimble Navigation in the year 2004 showed an outside defensive top mounted AR system. Wikitude, in the year 2008 made the AR Travel Guide for Android mobile phones.

AR nowadays: Google beta, in the year 2013 attempted the Google Glass—with web relationship by methods for Bluetooth. In 2015 Microsoft displayed two crisps out of the container new progressions: Windows Holographic and HoloLens (an AR goggles with heaps of sensors to indicate HD 3D pictures. Niantic in the year 2016, pushed Pokemon Go game for phones. The application propelled the gaming business up and made $2 million of each an essentially first week.

1.3 Industry 4.0

Lately, Ontario's assembling economy has entered what many are calling "Industry 4.0"—a reference to the fourth mechanical transformation past the basic robotization of the 1960s [7]. This new period of industry is characterized by the utilization of profoundly propelled computerization and information to improve proficiency and generation, including endeavors to associate apparatus and items utilizing the "Internet of Things." Scanners, sensors, enormous information examination, and exceedingly progressed and versatile robots are turning into the new standard. Robots are worked to aid the assembling of items through a joint effort with different robots and human laborers. They can be reinvented and utilized in a large number of assignments, as opposed to for a solitary errand like those of the 1960s. Sensors can advise makers on how to improve proficiency, revealing the exact minute when they will quit working and require fix or substitution to anticipate bottlenecks in the generation procedure. Huge information examination can enable makers to accelerate procedures and catch imperfections before items are sent out. Virtual and increased the truth are being utilized to plan and structure items and generation forms. Man-made reasoning can possibly plan and actualize answers for a wide assortment of generation and calculated issues. In these ways, Industry 4.0 is taking creation effectiveness to a dimension that has never been seen, and Ontario is directly at the cutting edge, creating an ideal this new time of assembling.

As seen in Fig. 2, Industry 1.0 focused on Mechanization, steam power, and weaving loom. Industry 2.0 focused on mass production, assembly line, and electrical energy. Industry 3.0 focused on Automation, Computers, and Electronics. An in-today's era, with the increasing boom of Internet of Things, Networks, Big Data, and Cyber-Physical Systems, the term Industry 4.0 came into existence.

The rising of new automated mechanical advancement, known as Industry 4.0, is a change that makes it possible to aggregate and research data across over machines, engaging snappier, continuously versatile, and progressively successful methodology to make a higher-quality product at diminished costs [9]. This gathering revolt will manufacture productivity, move money-related issues, develop mechanical advancement, and modify the profile of the workforce—finally changing the power of associations and areas.

Industry 4.0 is a name given to the present example of computerization and data exchange collecting progresses. It fuses advanced physical systems, the Internet of things, dispersed registering and scholarly figuring. Industry 4.0 is normally suggested as the fourth mechanical change (Fig. 3).

2 The Role of Augmented Reality in Industry 4.0

The term Industry 4.0 rises up out of the mix of new information advances and data examination with front line creation frameworks and strategies. The most agent features of this new time are smart affiliations and data.

We are starting at now living in the information time frame. According to Bernard Marr, Big Data ace, more data

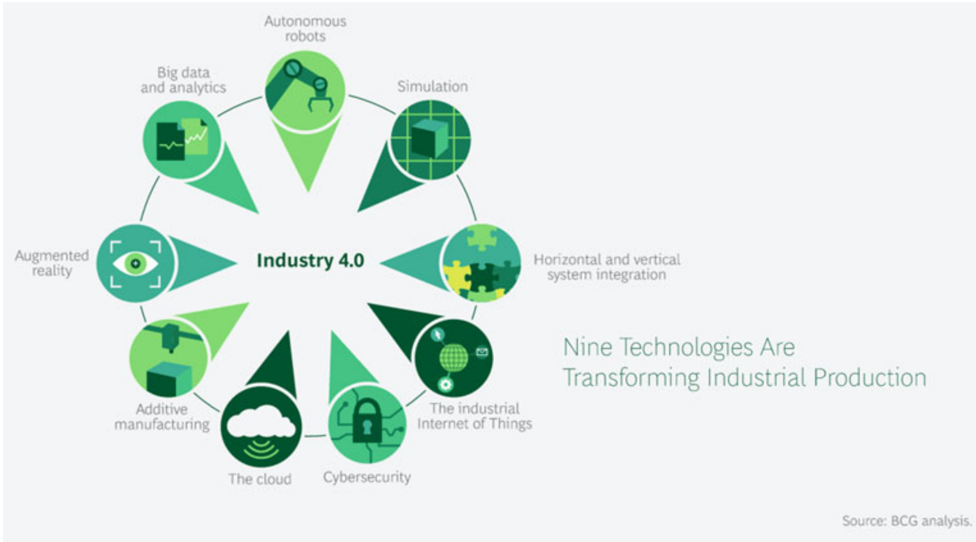


Fig. 3 Technologies transforming Industrial Production [10]

has been made over the latest 3 years than in the entire previous history of mankind. Just to get a little idea of the volume of data made, Google enlists more than 60,000 requests reliably.

In any case, this tremendous measure of data isn't adequate, what really makes it significant is the way wherein it can improve the essential initiative [11]. This is when splendid affiliations ended up being significant, the information must be colossal and appeared at the ideal time in an advantageous spot. In this new information time, machines and people are continually related, improving current methods.

The fourth mechanical rebellion does not depend upon one development yet rather a couple of, the blend of these headways is what can really improve the strategies and capability of organizations. Considering all these facts, what activity Augmented Reality is playing?

AR advancement passes on customers the chance to experience an augmented world by overlaying virtual information in reality [11]. Thusly the customer can be in contact with both the real and virtual world and get ceaseless data or estimations.

For industry 4.0, this can have a couple of focal points. It might be the perfect strategy to address noteworthy information for experts and workers in the association, empowering them to watch progressing information from the work they are performing. It is furthermore proper to give authorities information about the issue a machine is encountering, enabling them to see the customer immediate or even to contact an expert to get continuous assistance.

Another staggering great position AR passes on to Industry 4.0 is the probability of overhauling mechanical planning and learning while in the meantime lessening perils and costs.

Augmented Reality has experienced a brisk improvement is the most recent year and ordinary it is less complex to find another industry that is applying it to its activity. For a considerable number of individuals, their first contact with this development comes as a videogame or an application. Despite the way that the gaming business is benefitting by the mix of the virtual and authentic that AR gives, the actualities affirm that the potential uses of Augmented Reality go past this division.

Without a doubt, the best tech associations on earth are pointing their undertakings at the development that is set to change the way in which we see and speak with the world, and the AR publicize is required to overcome the Virtual Reality grandstand in the inevitable years. By 2020, the Augmented Reality exhibit is depended upon to hit $120 billion in pay, while the Virtual Reality publicize is required to hit $30 billion. This is an instance of how snappy the inventive market advances and how AR is outperforming the wants made by VR in the early extended lengths of progress.

The snappy improvement that AR is experiencing is taking it to different ventures and fields, anyway the focal points and experiences it gives makes the enlightening part the perfect fit for it. Augmented Reality is changing the activity instructor's play in the investigation lobby, they need to use courses of action that help their work, improving the learning technique of their understudies. Applying AR to their procedure gives progressively individualized learning and motivation to their understudies, among various central focuses.

Augmented Reality is credited an unprecedented potential for certain fields of utilization. Albeit Augmented Reality applications have been used successfully in restorative or military settings for quite a while, present day applications are as often as possible seen as separated game plans that are only important in a portrayed and static working environment.

Augmented-reality-based systems reinforce a variety of organizations, for instance, picking parts in a dispersion focus and sending fix rules over PDAs. These structures are at present in their beginning periods, anyway, later on, associations will use augmented reality to give workers consistent information to improve fundamental initiative and work frameworks.

As specified in [12] driving makers are utilizing augmented reality innovation to improve profitability, proficiency, and wellbeing in the work environment.

AR is changing the fate of work. From utilities, mining and assembling to retail and excitement, the appropriation will detonate as enterprises acknowledge colossal efficiency gains—any semblance of which have not been seen for a considerable length of time. As more organizations try to grasp the capability of AR, here are six different ways that driving edge producers are utilizing AR today:

Interfacing telecommuters: Enterprises can get gigantic advantages in a successful joint effort by enabling a specialist to see precisely what laborers see and direct them to finish errands. Specialists on the manufacturing plant floor can investigate apparatus or approach a remote master to fix a generation stoppage without trusting that the master will venture out to the office. Resource profitability will improve because of better usage.

Helping specialists in complex errands: Using AR to overlay guidelines have been demonstrated to diminish blunder rates in assembling get together undertakings by as much as 90%. Keen glasses can overlay exact directions onto the work territory and precisely control the expert through each progression, accordingly disposing of postponements, expanding the simplicity of cooperation, limiting interruptions and upgrading workforce the board.

Improving warehousing and co-ordinations: When proficient co-ordinations mean a genuine benefit, the capacity to improve warehousing productivity has colossal financial potential. Keen glasses are demonstrated to give 15% effectiveness enhancements to stockroom pick-and-spot tasks by adequately managing laborers and maintaining a strategic distance from slip-ups.

Upgrading preparing and supervision: AR preparing bundles empower immeasurably increasingly powerful learning results for specialists who need to comprehend complex gear or high-chance situations. Bosses are additionally ready to guide and survey a laborer's ability, bringing about higher quality work with fewer oversights.

Giving a common comprehension of business activity: AR innovation in the meeting room makes an abnormal state perspective on your entire business, demonstrating precisely what's going on and where. It enables administrators and organizers to convey viably utilizing ongoing information and examination while seeing precisely what's going on the shop floor—bringing about better operational choices over your business.

Wellbeing: Worker security is the No. 1 worry for each business, and it's no misrepresentation to state AR gadgets will spare lives. Associations will most likely screen working environments continuously and fundamentally lessen the "close miss" occurrences that are so ordinarily connected to fatalities.

The advanced coordinated effort innovation utilized in AR laborer arrangements can likewise make other developing ideas conceivable, including publicly supported master systems. Welcoming thoughts from broad gatherings, typically on the web, to take care of a typical issue can guarantee that specialists or different laborers in the field dependably approach the remote help they need. A specialist system administration can likewise make beneficial things not far off: Experts can creator insightful agendas for the up and coming age of augmented laborers, and more seasoned laborers can keep on contributing their insight in semi-retirement or even retirement.

2.1 Working of Augmented Reality

For AR a particular level of data (pictures, activities, accounts, 3D models) may be used and people will see the result in both ordinary and fabricated light. In like manner, customers consider being in reality which is advanced by PC vision, not under any condition like in VR.

AR can be appeared to be changed contraptions: screens, glasses, handheld devices, phones, head-mounted introductions. It wires advances like S.L.A.M. [13] (simultaneous concealment and mapping), criticalness following (rapidly, a sensor data figuring the section to the things), and then going with portions:

Cameras and sensors. Get-together data about customer's affiliations and sending it for getting ready. Cameras on devices are looking earth and with this data, a contraption finds physical things and produces 3D models. It may be thrilling obligation cameras, as in Microsoft Hololens, or standard phone cameras to take pictures/accounts.

Planning: AR contraptions at long last should act like little PCs, something present-day mobile phones starting at now do. Along these lines, they require a CPU, a GPU, streak memory, RAM, Bluetooth/WiFi, a GPS, etc. to have the choice to check speed, edge, heading, bearing in space, and so forth.

Projection: This prescribes a downsized projector on AR headsets, which takes data from sensors and tries robotized substance (a result of overseeing) onto a surface to see. Believe it or not, the utilization of projections in AR has not been totally grown yet to use it in business things or affiliations.

Reflection: Some AR contraptions have mirrors to help human eyes by seeing virtual pictures. Some have an “assortment of inconsequential bent mirrors” and the others have a twofold sided mirror that reflects light to a camera and to a customer’s eye. The fundamental point of such reflection ways is to play out a credible picture plan.

2.2 Types of Augmented Reality

Augmented Reality Technology is classified into various types [4]:

Marker-based AR: Nearly likewise allude it to picture confirmation, as it needs a noteworthy visual article and a camera to channel it. It may be whatever, from a printed QR code to imperative signs. The AR contraption, what’s more, realizes the position and heading of a marker to position the substance, on occasion. Along these lines, a marker begins pushed progressions for customers to see, in this manner pictures in a magazine may change into 3D models.

Marker-less AR: A.k.a. zone based or position-based augmented reality, that uses a GPS, a compass, a whirligig, and an accelerometer to give information dependent on the client’s zone. This information by then comprehends what AR content you find or get in a specific region. With the receptiveness of telephones, this kind of AR regularly passes on maps and headings, adjacent affiliations information. Applications meld occasions and data, business progressions pop-ups, course support.

Projection-based AR: Anticipating made light to physical surfaces, and once in a while allows to interface with it. These are the multi-dimensional pictures we have all seen in sci-fi motion pictures like Star Wars. It sees customer association with a projection by its changes.

Superimposition-based AR. Replaces the main see with an augmented, totally or to some degree. Article request foresees a key occupation, without it the whole thought is basically unfathomable.

2.3 Augmented Reality Devices

Numerous advanced gadgets as of now bolster Augmented Reality [6]. From cell phones and tablets to contraptions like Google Glass or handheld gadgets, and these advances keep on developing. For preparing and projection, AR gadgets and equipment, as a matter of first importance, have prerequisites, for example, CPU, presentations, cameras, sensors, accelerometer, spinner, advanced compass, GPS, and a number of things. The Fig. 4 shows the basic AR devices that are easily available in the market.

Gadgets reasonable for augmented reality fall into various classifications:

Cell phones (cell phones and tablets)—the utmost accessible and most suitable for AR versatile applications, extending from unadulterated gaming and diversion to business investigation, athletics, and long-range interpersonal communication. With the expanding accessibility of sensors inside cell phones and inside the world everywhere, an inquiry emerges about how this sensor information can be utilized by Augmented Reality (AR) gadgets. AR gadgets have customarily been constrained by the capacity of a given gadget’s exceptional arrangement of sensors. Interfacing sensors from different gadgets utilizing a Sensor Web could address this issue. Through utilizing this SensorWeb existing AR conditions could be improved and new situations made conceivable, with gadgets that beforehand couldn’t have been utilized as a feature of an AR domain. In [15], the authors have proposed an architecture named SIXTH which is a middleware for generating sensor web that allows devices to influence diverse exterior sensors in the interior of its surroundings so that it can help in generating better-off AR experiences.

Extraordinary AR gadgets, structured essentially and exclusively for augmented reality encounters. One precedent is head-up showcases (HUD), sending information to a straightforward presentation legitimately into the client’s view. Initially acquainted with train military warriors pilots, presently such gadgets have used in flight, car industry, fabricating, sports, and so on.

AR glasses (or shrewd glasses)—Google Glasses, Meta 2 Glasses, Laster See-Through, Laforge AR eyewear, and so on. These units are fit for showing warnings from your cell phone, helping mechanical production system laborers, and get to the content without hands, and so on.

AR contact focal points (or keen focal points), making Augmented Reality one stride much more distant. Makers like Sony and Samsung have reported the advancement of AR focal points. Individually, Samsung is taking a shot at focal points as the assistant to cell phones, while Sony is planning focal points as isolated AR gadgets (with highlights like taking photographs or putting away information).

Virtual retinal presentations (VRD), making pictures by anticipating laser light into the human eye. Going for splendid, high difference and high-goals pictures, such frameworks yet stay to be made for handy use.

The Augmented Reality devices can also be classified into four major categories [16] as mentioned in Fig. 5:

Fig. 4 AR devices [14]

Head Up Displays (HUD)

As the locally available controllers on flights turned out to be progressively perplexing, the data handling assignments for pilots expanded with an included number of sensors, aeronautics and flight controls. It is significant for pilots to concentrate on what's going on outside as opposed to taking a gander at the variety of data inside the cockpit. Head up displays were, for the most part, developed for mission basic applications like flight controllers and weapons framework dashboards. Basic data is anticipated on straightforward screens mounted before the pilot. This empowers pilots to look forward outside as opposed to glimpsing down inside the cockpit. Like Grub's collimating reflector, HUDs attempted to tackle the issue of moving concentration by utilizing a kind of collimating projector. The data anticipated is collimated (parallel light beams) concentrated on endlessness so the pilot's eyes don't have to refocus to see outside the cockpit.

A standard HUD contains three principle segments; a projector unit, a review glass (combiner) and a PC (image generator). HUDs help increment situational mindfulness by diminishing the move of the center for pilots. Progressively heads up presentations have been discovering ways into new car plans.

Helmet Mounted Displays

The following intelligent advance for heads up showcases was to move from the windshield to the cap. Progressively protective cap mounted showcases which utilize the equivalent hidden standards of heads up presentations are being utilized in flying and different ventures.

Holographic Displays

Promoted in the Star Wars arrangement, Minority report and the Iron man arrangement in the ongoing occasions, these sorts of presentations utilize light diffraction to create three-dimensional types of articles in genuine space. The way that holographic presentations don't expect clients to wear any apparatus to see them is one of their most noteworthy points of interest. These sorts of displays have dependably been in the domain of sci-fi and have as of late begun picking up footing with items like Looking Glass and Holovect.

Smart Glasses

As the innovation changed from basic applications in safeguard and avionics to financially accessible items, savvy glasses have turned out to be one of the more prominent kinds of increased reality gadgets. Like their name proposes, these are glasses that expand your vision. Smart glasses are of two kinds:

Optical transparent/see-through

In Optical see-through glasses, the client sees reality straightforwardly through optical components, for example, holographic waveguides and different frameworks that empower graphical overlay on this present reality. Microsoft's HoloLens, Magic Leap One, and the Google Glass are late instances of optical transparent shrewd glasses.

Video see-through

With these kinds of smart glasses, the client sees a reality that is first caught by a couple of cameras mounted on the showcase. These camera perspectives are then joined with PC created symbolism for the client to see. The HTC Vive VR headset has an inbuilt camera which is regularly utilized for making AR encounters on the gadget.

Handheld AR

Albeit handheld AR is a kind of video sees through, it merits uncommon notice. The ascent of handheld AR is the tipping point for the innovation being genuinely inescapable. Increased reality libraries like ARKit, ARCore, MRKit, have empowered refined PC vision calculations to be accessible for anybody to utilize. In handheld or portable AR, all you need is a cell phone to approach a large group of AR encounters.

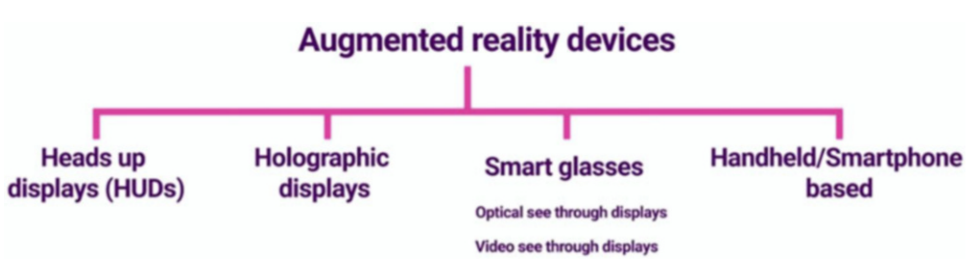


Fig. 5 Classification of augmented reality devices [16]

3 Technological Requirements for Augmented Reality

There are certain specific requirements for Augmented Reality in industries [17]. The following requirements referenced are organized by measurement of time (improvement and mix, set-up, task).

Prerequisites During Improvement and Joining

- Cost-viability: The normal return needs to legitimize the cost that is required during improvement and joining, separately the venture expenses of the AR application.
- Information security: If information recording or position following prompts a reconnaissance of representatives, certain laws or guidelines apply, and may make clashes with specialists and their gatherings. In this way, any gathering of information ought to be settled upon and information security must be ensured.
- Relevant guidelines: Regulations, for example, work wellbeing guidelines or cleanliness determinations, are to be considered during the plan and mix of AR applications

Prerequisites During Set-up

- Set-up time: The time required for the set-up of AR applications inside the modern condition ought to be insignificant. This may incorporate essential repeating forms, for example, adjustment or cleaning
- Framework unwavering quality: The application ought to require insignificant support and be as dependable as could be allowed

Requirements During the Task

- The exactness of introduction: Precision in the arrangement of genuine and virtual items is important to lessen potential blunders
- Ongoing ability: Tracking and perception of articles ought to be performed progressively so as to permit an increasingly natural connection with the application, and diminish dangers of mistakes or movement ailment
- Ergonomy: AR applications for the most part work on the human side of a human-machine interface.

Their plan and activity ought to in this manner be human-driven and consider certain human factors, for example, decreased consideration or eye fatigue during longer occasions of activity. The exhibited necessities have been gathered with a cross-application approach and demonstrate a fairly low dimension of detail. This does not constrain them to the modern territory, with the goal that they rather may likewise apply for applications in different zones, for example, pilot training programs.

As mentioned by Lorenz et al. in [18], the requirements can also be classified by the accompanying:

Client Requirements

Following necessities can be recognized for an AR upkeep laborer emotionally supportive network covering diverse modern use cases:

- Convenient access to all applicable documentation (for example manual, audio-visual, photograph)
- Summary about required instruments, materials and extra parts for a particular upkeep task
- Assisted direction with AR anticipated 3D objects (particularly for bigger machines)
- Workflow direction with the assistance of 3D activities
- Adding to the current documentation during the errand by taking notes or pictures and so on.
- Accessing live telemetry information of explicit machine parts while being available at this part
- Cross-referencing upkeep cases to reuse arrangements built up in a comparable case
- Recording measurable information for future arranging of comparable assignments
- The alternative to open a video meeting to a specialist to get extra data about the current case
- An include for the master and the upkeep laborer, to share reports (content, picture, video) and increase the common live feed with bolts, hovers, and so forth., to feature focal points
- Offline mode to work in territories without Wi-Fi association
- Hands-free task

Technical Requirements

To help the support laborers with AR a few specialized conditions should be met:

- Data association (favored remote) at all areas of utilization
- Connectivity to a focal information stockpiling framework, to store general assignment information and documentation
- Connectivity to a framework that totals the live telemetry information of every single included machine
- Connectivity to extra frameworks for example for extra part requesting
- Operation time of in any event 4 h
- Minimum of 8 Mbit/s web association for sharing documents or a video gathering at creation webpage

Ecological and Regulative Requirements

Any AR equipment utilized in the modern condition will be presented to earth, fluids (likewise destructive), mechanical perils and electromagnetic impedance. Further, the AR equipment must be usable with any required security rigging utilized by the specialist. In this setting an AR gadget needs to meet the accompanying ecological and regulative prerequisites:

- Usable with a hard cap, wellbeing glasses as well as commotion insurance (close by or incorporated in the hardware)

- usable with wellbeing gloves (remuneration for debilitated signal acknowledgment and contact input)
- The gadget must almost certainly support a tumble from a statue of in any event 1.2 m
- The gadget must be impervious to water, airborne residue, destructive materials, scratching as well as electromagnetic impedance (can likewise be accomplished with a replaceable spread)
- The defensive measures ought not to obstruct the usefulness of the gadget (for example remote network)

4 Applications of Augmented Reality to Industry 4.0

For the most part, the utilization of AR to the business space is appropriate since it inconceivably improves the correspondence in thing structure and creation progression: it recognizes and avoid plan botches in starting times of the improvement method; it reduces the number of physical models and extras time and cost for endeavors. AR is considered as a critical instrument for improving and reviving thing and technique headway in various mechanical applications.

The depiction of current AR applications plans to reinforce the finish of general essentials. Along these lines, a wide scope of present-day applications is verified, yet they are by no techniques complete. Mechanical AR applications are ordinary to perform well in the going with regions:

- Product structure: Visualization of wise 3D-models in prototyping and presentation
- Plant structure: Visualization of an orchestrated organization inside a certifiable generation line condition
- Training: Augmented getting ready re-enactment or progression of creation frames in veritable circumstances
- Production help: Virtual assistance structure through the impression of setting unstable information on creation frames, manual get-together and things at the shop-floor level
- Quality affirmation: AR-based assistance through the impression of sensor data or imperfection the board information
- Production collaborations: Support of indoor course through AR-set up together bearing or information as for picking frames
- Remote support: AR-based remote relationship for the assistance of care staff on the region, teleoperating upkeep robots or assignment of smart and virtual bearings in the midst of the upkeep of age workplaces.

Despite the applications, a couple of makers moreover depict express hindrances and necessities that have been viewed in the midst of progression and testing.

Apart from these specific applications to Industry 4.0, there are contributions of a number of researchers who have worked in the field of Augmented Reality and proposed their architectures in a variety of fields. Helen Papagiannis in [19] centers around AR Joiner arrangement, which applies 2D planar video to form novel scenes using different bordered AR markers crosswise over both physical and virtual existence to make new encounters of seeing. Xi et al. [20] have displayed three use cases to indicate how AR can conceivably bolster increasingly proficient farm board exercises: water quality administration, remote joint effort, and meeting room exchange specifying the importance of augmented reality in the management of future agriculture farm. V. Gay-Bellile et al. in [21] address the demanding issue of vision-based limitation in an urban setting. It quickly depicts their commitments in huge conditions modeling and exact camera restriction. Galvão and Zorzal in [22] propose different health education related different applications with the help of Augmented Reality. Blum et al. in his work [23] proposes an ultrasound simulator using augmented reality that helps in a medical imaging modality. As mentioned in [24] by Radu, Augmented Reality also has a powerful impact in the field of education. In [25], Waechter et al. converses various approaches in which people who are tracking in real time can inspire the areas of Augmented Reality and additional vision based applications. In [26] Bichlmeier et al. covers the techniques and intermediate results of the ARAV—Augmented Reality Aided Vertebroplasty venture that started to design an AR framework dependent on a stereo video see through head mounted presentation that is forever accessible in the operation room (OR) and thus shows the importance of AR in clinical domain.

5 Virtual Reality and Speech Recognition in Industry 4.0 Trends

5.1 Difference Between Virtual and Augmented Reality

Virtual Reality and Augmented Reality are two of the utmost problematic and unmistakable advances nowadays. Both keep creating and showing new applications and game plans they can provide. In spite of the way that they are eminent round the globe, the differences among them are not flawless in any way shape or form. These are the three major differences between AR and VR [27]:

Drenching

The essential complexity amongst these two advances is the immersion they provide. Augmented Reality makes an absolutely PC created world, everything the customer perceives is a phony amusement, so the customer loses contact with the certifiable situation. On the other hand, Augmented Reality redesigns reality by adding mechanized information to it, so the customer is still in contact with the authentic condition in the midst of the AR experience. This empowers the customer to collaborate with the "extended" objects while existing in contact with this present reality.

Devices

Inundation isn't the standard refinement amongst these two types of progress, the gadgets they practice to pass on inventive encounters are additionally stand-out between them. VR utilizes headsets that inundate the client's vision and hearing into the virtual world. AR is given from an undeniably general gathering of contraptions: AR headsets, PCs, tablets, telephones... Don't disregard that AR keeps the client in contact with this present reality, that is the thing that has the best effect between the gadgets utilized.

Edtech Application

The two headways are associated with different organizations, as we have quite recently discussed here, yet maybe the business where they can turn into the most is preparing. Both of them offer the chance to annoy ordinary approaches, yet their applications as edtech game plans are extraordinary. VR can be used to immerse understudies into bona fide universes, for example, making it a not too bad response for theoretical works out. In any case, the guideline feature of AR is the ability to interface with the "extended" world that is the intention it can offer understudies progressively rational activities.

5.2 Speech Recognition

Speech recognition is innovation that can perceive verbally expressed words, which would then be able to be changed over to content. A subset of speech recognition is voice recognition, which is the innovation for distinguishing an individual dependent on their voice [28]. In this time of new innovation as mentioned in [29] where the Internet of Things is the greatest subject of the day, there are different advances that occasionally don't get the consideration that IoT gets, that doesn't mean these advances don't greatly affect our day by day lives. Speech recognition is one of these advancements that is having incredible effects in Smart homes, however considerably greater effects in Smart Industries by streamlining efficiency in modern conditions where assets are constrained. Speech recognition is the capacity of a machine or program to get and decipher verbally expressed words and complete the directions.

Speech recognition is making head routes in Smart Home arrangements with Google Home and Amazon's Alexa these gadgets are making home robotization a lot simpler through voice recognition. These two items add insightful voice control to any associated items to enable clients to direction home highlights like playing music, lighting up, diminishing or turning lights on or off, control TV, warming and air controls and numerous other shrewd home controls.

In this day and age of associated gadgets having hands free computerization is adding another dimension to the associated gadget and Smart Industry Solutions, by exploiting new innovation, a business can eliminate blunders made by representatives, sets aside cash and furthermore expands the efficiency of their specialists. This is giving adopters an essential favorable position in their business sectors and putting their business on the forefront of innovation.

Voice recognition has developed as of late as far as speed and precision which is the reason private and modern enterprises are utilizing them increasingly more to make mechanical answers for help in the streamlining of the business.

The most widely recognized situation we see are clients talking into a gadget and having that data recorded, use cases like talking into a gadget to type that information out for individuals with incapacities, this has been utilized for a long time and is an extraordinary precedent. Voice recognition innovation has unlimited potential outcomes.

Machine to Machine correspondence in modern robotization is currently being executed in production lines to build correspondence and oversee a lot of information that is being created continually by the various procedures of the machines cooperating in assembling ventures.

Voice recognition is additionally utilized as a rule for telecommuters in service organizations who convey administration professionals to assess the distinction work destinations. The specialists would regularly bear bulky hardware to log information from the diverse reviewed destinations to transmit that information back to a focal office. Presently with voice recognition, these administration experts can now effectively log the essential information by just discussing directions. There are numerous applications for speech recognition in modern situations that can encourage streamlining business process, early adopters are utilizing them to tackle the issues that they face with client blunder and not having the assets accessible to them, these early adopters are driving the way to others seeing the incentive in voice recognition innovation.

5.3 Automated Speech Recognition Technology

Speech recognition is power-driven by Artificial Intelligence frameworks that are continually refreshing dependent on a huge number of client communications. These frameworks, and the exactness they bear require the sort of enormous handling power and back-end information that lives in the cloud; and for certain clients, the possibility of any open cloud execution raises worries about information security, get to control, client protection and legitimate hazard [30, 31] (Fig. 6).

Automated Speech recognition is the capacity of machines to translate discourse so as to do directions or produce content. A significantly related zone is programmed speaker recognition, which is the capacity of machines to distinguish people dependent on the qualities of their voices. Engineered discourse, or synonymously message to-discourse, is capable of being heard discourse created by machines from standard PC put away content. These controls are firmly related to the grounds that the two of them include an investigation and comprehension of human discourse creation and discernment instruments. Specifically, the examination of discourse into its individual parts (telephones) and the portrayal of the acoustic waveforms of these segments are normal to the two orders. Speech recognition and discourse amalgamation are likewise firmly coupled at the applications level—for instance, for remote database gets to where visual showcases are not accessible. The utilization of speech recognition for information and synthesized speech for production is an amazing blend that can change any phone into a completely clever hub in a computer network [33].

5.4 Importance of Speech Recognition in Industries

As specified by Brian Ballard in [28], help for hands-on specialists might be headed from an innovation that has seen breakout accomplishment in the purchaser world. Computerized aides like Amazon Echo and Apple's Siri given individuals a chance to cooperate with gadgets, discover data on the web and perform complex undertakings, all through the intensity of the voice. Envision how that could help specialists who should be associated with data however don't have hands allowed to work a console or touchpad.

In the modern condition, that ability needs to pursue specialists around the manufacturing plant or distribution center. Luckily, voice is being packaged with another innovation to help hands-on laborers: savvy glasses. Keen glasses offer a survey experience that doesn't expect individuals to turn away based on what they're doing to take a gander at a presentation screen or paper report. Rather, these head-mounted presentations interface specialists to data like agendas, maps, item documentation, and information yields from associated machines and even instructional recordings in their field of view. It's a piece of a subset of expanded/blended reality innovations that we call helped reality.

The utility of AR and shrewd glasses brings up an issue of UX configuration: How should hands-on specialists cooperate with data introduced to them on a presentation gadget that isn't outfitted with customary contributions, in work situations that don't take into account them to hold or connect with even a straightforward cell phone or touchscreen?

IoT enabled Smart Speaker as in [34] can be used. Voice communication takes care of this issue. Specialists can issue basic voice directions like "mark all means the total" or "open next assignment" to summon the incredible abilities of the framework. Some product considers voice-to-content interpretation, transforming spoken words into records, explanations on an image or procedure, or correspondences with a remote

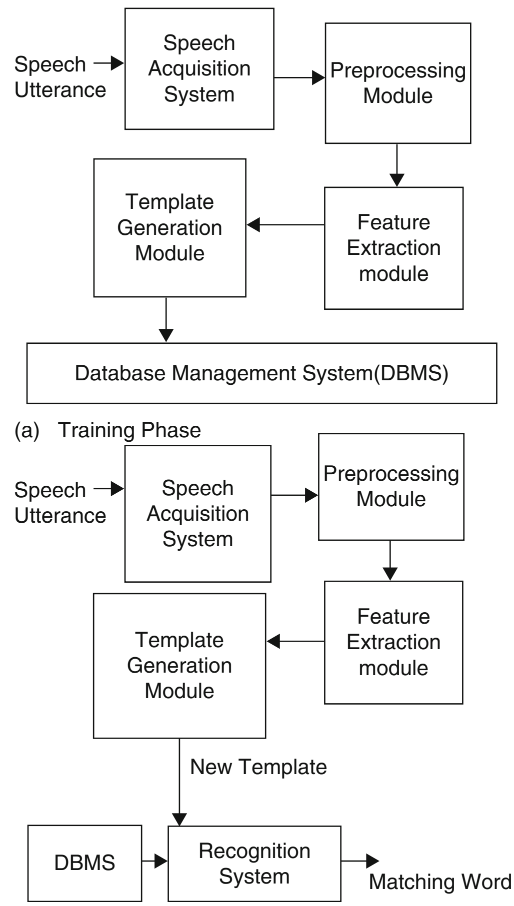


Fig. 6 Block diagram of automatic speech recognition [32]

associate or master. As man-made brainpower abilities develop, some product will probably suit setting based questions ("Where does this part go?" or "Am I doing this right?") will enable individuals to adapt quickly and work quicker with less exertion, more prominent certainty and fewer mistakes.

Organizations that adopt a go-moderate strategy on voice-empowered work procedures are passing up on a major change and might put themselves, their accomplices and clients, and their specialists in danger of being out-created by contenders that have effectively figured out how to quicken with a voice as an accessible instrument to the workforce.

The author in [7] state to the sellers providing equipment and AR gadgets, similar to Google, Vuzix and RealWear, for the mechanical endeavor, that they have to offer progressively powerful help for voice usefulness, with better quality mouthpieces, rough structure and onboard clamor decrease that address the issues of the modern work environment.

Expanding interest for speech-driven route frameworks and workstations is advancing development in the equipment and programming fragments. Reconciliation of voice-empowered in-vehicle infotainment frameworks is picking up ubiquity over the globe as a few nations start "sans hands" guidelines that administer the utilization of cell phones while doing any concentrating errands [13, 24–27, 35–45].

6 Conclusion

This chapter has presented the basic idea of Augmented Reality and Industry 4.0. The concepts about the working of Augmented Reality is covered along with its types. A brief discussion on the devices that uses Augmented Reality Technology and are useful in Industry 4.0 is carried out. I have tried to identify various technological requirements for Augmented Reality in Industry 4.0. These requirements have been classified and analyses on the basis of various categories. The chapter also briefs about the concept of Speech Recognition, its working technology and its usefulness in Industry 4.0 when blended with Virtual Reality. The literature presented in this paper helps in concluding that Augmented Reality is indeed an important pillar for Industry 4.0.

References

1. Solanki, A., & Nayyar, A. (2019). Green Internet of Things (G-IoT): ICT Technologies, Principles, Applications, Projects, and Challenges. In Handbook of Research on Big Data and the IoT (pp. 379-405). IGI Global.
2. Batth, R. S., Nayyar, A., & Nagpal, A. (2018, August). Internet of Robotic Things: Driving Intelligent Robotics of Future-Concept, Architecture, Applications and Technologies. In 2018 4th International Conference on Computing Sciences (ICCS) (pp. 151-160). IEEE.
3. Vikram Puri (2019) "The Internet Of Things, Augmented Reality And Virtual Reality: A Fruitful Synergy in Industry 4.0" https://electronicsforu.com/technology-trends/tech-focus/iot-ar-vr-fruitful-synergy-industry-4 Accessed 11 June 2019
4. Calicut IPCS (2018) "Explanation of Augmented Reality (AR) – Application and Cassification", https://ipcsautomation.com/blog-post/explanation-of-augmented-reality-ar-application-classification/ Accessed 6, June 2018
5. Nayyar, A., Mahapatra, B., Le, D., & Suseendran, G. (2018). Virtual Reality (VR) & Augmented Reality (AR) technologies for tourism and hospitality industry. *International Journal of Engineering & Technology*, *7*(2.21), 156-160.
6. "What is Augmented Reality and how does it work?"https://thinkmobiles.com/blog/what-is-augmented-reality/
7. Francesco De Pace∗, Federico Manuri and Andrea Sanna (2018) "Augmented Reality in Industry 4.0" http://www.imedpub.com/articles/augmented-reality-in-industry-40.php?aid=22168 Accessed 20 March, 2018
8. Trillium Network for advance Manufacturing (2017), "The rise of Big Data and Industry 4.0" http://trilliummfg.ca/the-rise-of-big-data-and-industry-4-0/ Accessed 9 November, 2017
9. Industry 4.0 Certification https://certification.cc/industry-4-0/
10. (2019) "Embracing Industry 4.0 and rediscovering Growth" https://www.bcg.com/en-in/capabilities/operations/embracing-industry-4.0-rediscovering-growth.aspx
11. R. Gupta., S. Tanwar., S. Tyagi, N. Kumar, "Tactile Internet for Industry 4.0 in 5G Era: A Comprehensive Review", International Journal of Communication System, pp. 1-52, 2019
12. Augmented reality enables smart, handsfree productivity (Whitepaper). https://assets1.dxc.technology/manufacturing/downloads/Augmented_Reality_Insight.pdf
13. Blog (2017) "Know the Augmented Reality Technology. How does AR work?" https://www.newgenapps.com/blog/augmented-reality-technology-how-ar-works Accessed 23 November 2017
14. Ambrus and Lonau GBR, "Augmented Minds" https://www.augmented-minds.com/en/augmented-reality/ar-hardware-devices/
15. A. G. Campbell and D. Carr, "Giving Mobile Devices a SIXTH Sense : Introducing the SIXTH Middleware for Augmented Reality Applications," pp. 245–246.
16. Kore (2018) "Understanding the different types of AR Devices" https://uxdesign.cc/augmented-reality-device-types-a7668b15bf7a Accessed 9 September, 2018
17. Quandt, M., Knoke, B., Gorldt, C., Freitag, M., & Thoben, K. D. (2018). General Requirements for Industrial Augmented Reality Applications. Procedia CIRP, 72(1), 1130–1135.
18. Lorenz, M., Knopp, S., & Klimant, P. (2018, October). Industrial Augmented Reality: Requirements for an Augmented Reality Maintenance Worker Support System. In 2018 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct) (pp. 151–153). IEEE.
19. Papagiannis, H. (2009, October). Augmented Reality (AR) joiners, a novel expanded cinematic form. In 2009 IEEE International Symposium on Mixed and Augmented Reality-Arts, Media and Humanities (pp. 39–42). IEEE.
20. Xi, M., Adcock, M., & McCulloch, J. (2018, March). Future Agriculture Farm Management using Augmented Reality. In 2018 IEEE Workshop on Augmented and Virtual Realities for Good (VAR4Good) (pp. 1–3). IEEE.
21. Gay-Bellile, V., Lothe, P., Bourgeois, S., Royer, E., & Collette, S. N. (2010, October). Augmented reality in large environments: Application to aided navigation in urban context. In 2010 IEEE International Symposium on Mixed and Augmented Reality (pp. 225–226). IEEE.
22. Galvão, M. A., & Zorzal, E. R. (2013, May). Augmented reality applied to health education. In 2013 XV Symposium on Virtual and Augmented Reality (pp. 268–271). IEEE.
23. Blum, T., Heining, S. M., Kutter, O., & Navab, N. (2009, October). Advanced training methods using an augmented reality ultrasound simulator. In 2009 8th IEEE International Symposium on Mixed and Augmented Reality (pp. 177–178). IEEE.
24. Radu, I. (2012, November). Why should my students use AR? A comparative review of the educational impacts of augmented-reality. In 2012 IEEE International Symposium on Mixed and Augmented Reality (ISMAR) (pp. 313–314). IEEE.
25. Waechter, C. A., Pustka, D., & Klinker, G. J. (2009, October). Vision based people tracking for ubiquitous Augmented Reality applications. In 2009 8th IEEE International Symposium on Mixed and Augmented Reality (pp. 221-222). IEEE.
26. Bichlmeier, C., Ockert, B., Heining, S. M., Ahmadi, A., & Navab, N. (2008, September). Stepping into the operating theater: ARAV—augmented reality aided vertebroplasty. In Proceedings of the 7th IEEE/ACM International Symposium on Mixed and Augmented Reality (pp. 165–166). IEEE Computer Society.
27. Seabery "3 Differences between Augmented Reality (AR) and Virtual Reality (VR)" https://emerj.com/ai-sector-overviews/ai-for-speech-recognition/
28. Ayn De Jesus (2019) "AI for Speech Recognition – Current Companies, Technology, and Trends" https://emerj.com/ai-sector-overviews/ai-for-speech-recognition Accessed 16 February 2019
29. John Walker (2017) "Voice Recognition Applications to Automate Industrial Operations" http://www.vensi.com/voice-recognition-applications-to-automate-industrial-operations Accessed 8 June, 2017
30. Brian Ballard (2017) "The next big innovation in industrial enterprise is voice. What's the holdup?" https://internetofthingsagenda.techtarget.com/blog/IoT-Agenda/The-next-big-innovation-in-industrial-enterprise-is-voice-Whats-the-holdup Accessed 29 June, 2017
31. Singh, S. P., Nayyar, A., Kumar, R., & Sharma, A. (2019). Fog computing: from architecture to edge computing and big data processing. The Journal of Supercomputing, 75(4), 2070-2105.
32. J. Vajpai and A. Bora, "Industrial Applications of Automatic Speech Recognition Systems," vol. 6, no. 3, pp. 88–95, 2016.
33. John A. Oberteuffer "Commercial Applications of Speech Interface Technology: An Industry at the Threshold" https://www.nap.edu/read/2308/chapter/25

34. Vora J, Tanwar S, Tyagi S, Kumar N & Rodrigues J P C, "Home-based Exercise System for Patients Using IoT Enabled Smart Speaker", IEEE 19th International Conference on e-Health Networking, Applications and Services (Healthco m-2017), Dalian University, Dalian, China, 12-15 October 2017, pp. 1-6.(Indexed in IEEE-Xplore, SCOPUS)
35. "Voice and Speech Recognition Market Size, Share & Trends Analysis Report, By Function, By Technology (AI, Non-AI), By Vertical (Healthcare, BFSI, Automotive), And Segment Forecasts, 2018 – 2025" https://www.grandviewresearch.com/industry-analysis/voice-recognition-market
36. P. Stief, J. Dantan, A. Etienne, and A. Siadat, "General Requirements for Industrial Augmented Reality France Applications new methodology to analyze the functional and physical architecture of existing products for an assembly oriented product family identification," Procedia CIRP, vol. 72, pp. 1130–1135, 2018.
37. P. Stief, J. Dantan, A. Etienne, and A. Siadat, "General Requirements for Industrial Augmented Reality France Applications new methodology to analyze the functional and physical architecture of existing products for an assembly oriented product family identification," Procedia CIRP, vol. 72, pp. 1130–1135, 2018.
38. A. Kumari., S. Tanwar., S. Tyagi, N. Kumar, M. Maasberg, K. K. R. Choo "Multimedia Big Data Computing and Internet of Things Applications: A Taxonomy and Process Model", Journal of Network and Computer Applications, 124:169-195, 2018.
39. A. Kumari., S. Tanwar., S. Tyagi, N. Kumar, R. Parizi, K. K. R. Choo "Fog Data Analytics: A Taxonomy and Process Model", Journal of Network and Computer Applications, 128:90-104, 2019.
40. Kumari, A., Tanwar, S., Tyagi, S., & Kumar, N. (2018). Verification and validation techniques for streaming big data analytics in internet of things environment. IET Networks, 8(2), 92–100.
41. J. Vora, S. Kanriya, S. Tanwar, S. Tyagi, N. Kumar, M. S. Obaidat, "TILAA: Tactile Internet-based Ambient Assistant Living In Fog Environment", Future Generation Computer Systems, Vol 98, pp. 635-649,, 2019.
42. Kumari A., Tanwar S., Tyagi S., Kumar N., "Fog Computing for Healthcare 4.0 Environment: Opportunities and Challenges", Computers & Electrical Engineering, Volume 72, pp. 1-13, 2018.
43. Vora J, Tanwar S, Tyagi S, Kumar N & Rodrigues J P C, "FAAL: Fog Computing-based Patient Monitoring System for Ambient Assisted Living", IEEE 19th International Conference on e-Health Networking, Applications and Services (Healthcom-2017), Dalian University, Dalian, China, 12-15 October 2017, pp. 1-6.
44. Nayyar, A., & Nguyen, G. N. (2018). Augmenting Dental Care: A Current Perspective. Emerging Technologies for Health and Medicine: Virtual Reality, Augmented Reality, Artificial Intelligence, Internet of Things, Robotics, Industry 4.0, 51-67.
45. Pandey, N., Lavingia, A., & Lavingia, K. (2015). ANALYZING THE PERFORMANCE OF OPTICAL SYSTEM USING DIFFERENT MODULATION TECHNIQUES. International Journal of Advance Engineering and Research Development, 2(12).

Kruti Lavingia is working as an Assistant Professor in the Computer Science and Engineering Department, Institute of Technology at Nirma University since August 2011. She has experience of more than 10 years in the field of teaching. She has obtained her BTech degree in Information Technology from Nirma University, Ahmedabad and MTech degree in Computer Science and Engineering from Bhagwant University, Ajmer. Her research interests are Software Engineering, Internet of Things and Fog Computing.

Dr. Sudeep Tanwar is an Associate Professor in Computer Science and Engineering Department at Institute of Technology, Nirma University, Ahmedabad, Gujarat, India. He is visiting Professor at Jan Wyzykowski University in Polkowice, Poland and University of Pitesti in Pitesti, Romania. He received B.Tech in 2002 from Kurukshetra University, India, M. Tech (Honor's) in 2009 from Guru Gobind Singh Indraprastha University, Delhi, India, and Ph.D. in 2016 from Mewar University, Chittorgarh, Rajasthan, India with specialization in Wireless Sensor Network. He has authored/coauthored more than 100 technical research papers in leading journals and conferences from IEEE, Elsevier, Springer, Wiley, etc. Some of his research findings are published in top-cited journals such as IEEE Transactions on TVT, IEEE Transactions on Industrial Informatics, Applied Soft Computing, Journal of Network and Computer Applications, Pervasive and Mobile Computing, International Journal of Communication System, Telecommunication System, Computer and Electrical Engineering and the IEEE Systems Journal. He has also published three edited/authored books with International/National Publishers. He has guided many students leading to M.E./M. Tech and guiding students leading to Ph.D. He is an Associate Editor of IJCS—Wiley and Security and Privacy Journal—Wiley. His current interest includes Wireless Sensor Networks, Fog Computing, Smart Grid, IoT, and Blockchain Technology. He was invited as Guest Editors/Editorial Board Members of many International Journals, invited for keynote Speaker in many International Conferences held in Asia and invited as Program Chair, Publications Chair, Publicity Chair, and Session Chair in many International Conferences held in North America, Europe, Asia and Africa. He has awarded best research paper awards from IEEE GLOBECOM 2018, IEEE ICC 2019, and Springer ICRIC-2019.

Robotics and Industry 4.0

Ruchi Goel and Pooja Gupta

Abstract

Industry 4.0 also known as fourth revolution is a new era in which industry will deal with technologies like Robotics, Automation, Artificial Intelligence (AI), and many more. The adoption of robots in Industries worldwide is on the high rise. Robots and human both have their own strengths and limitations. Working together in safe manner both will provide better quality product with high accuracy in less time. The main aim of Robotics and Industry 4.0 is to improve productivity, produce high quality product at low price and meet customer expectation. In this chapter we have discussed role of Robotics and Automation in Industry 4.0, pros and Cons of Robotics in Industry 4.0, various challenges and its applications.

Keywords

Artificial Intelligence (AI) · Artificial General Intelligence (AGI) · Artificial Intelligence in Education (AIED) · ROV (Remote Operational Vehicles) · Robotics · Industry 4.0

1 Introduction

The prevailing technology in contemporary era is the adaptive developments of Artificial Intelligence. This is being evolved over decades and enormously growing. The industry is coming up with new technological products almost on daily basis. Starting from the mobile phones, smart watches and other applications, we are receiving new updates at very quicker rate. New services and features are adding on regularly. Industry is providing conveniences and features at a faster rate even before one feel the need of that service. All this is being possible to happen because of the tremendous growth in the field of Artificial Intelligence and its adaptive processes. Moreover, the collaboration of AI to Machine Learning and then to Deep Learning has done tremendous in the area. The Fig. 1 shows how Artificial Intelligence, Machine learning and deep Learning are linked with each other. Artificial Intelligence is the process where a computer/machine just acts as a human being. Machine learning is a subset of AI that based on learning examples [1], train the system and then convert it to adaptive learning. Deep Learning is a subset of machine learning that works on Multilayer Models.

It is known to all that human do a variety of work and are busy in work 16 h of a day. Now, here the question arises; what we are exactly? Are we humans or machines. With the help of machines, it has been possible to accomplish variety of work in a less span of time to achieve anything. Figure 2 shows the Human and the Machine (ROBOT); just looking like a Human Being. This industrial development (Robotics) enable human to concentrate only on solving specific problems while, repetitive kind of task can be done by machine.

There are two kinds of Artificial Intelligence technologies. Narrow AI and Strong AI. Narrow AI is ability of computer to solve specific kind of problem to perform specific task.eg. self-driving car, Siri are powered by narrow AI. General AI, Strong AI or Artificial General Intelligence (AGI) are another name for strong AI. Currently, AGI does not exist. AI is within machine that give ability to interact it with physical world. In Robotics we get intelligent agent that can act accordingly. Further, advancement in AI has enable a lot of transformation in business. The progress of AI can be classified in three waves. The First Wave, Second Wave and the Third Wave. Figure 3 shows how the business and industries transformed during these waves.

R. Goel · P. Gupta (✉)
Computer Science Department, Maharaja Agrasen Institute of Technology, GGSIPU University, Rohini, India

A. Nayyar, A. Kumar (eds.), *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-14544-6_9

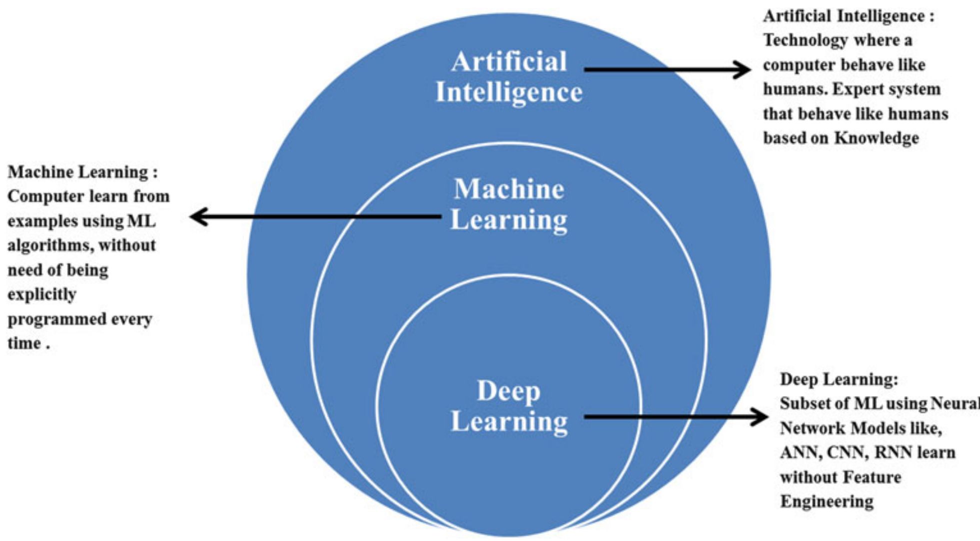


Fig. 1 Artificial Intelligence to Machine learning to Deep Learning

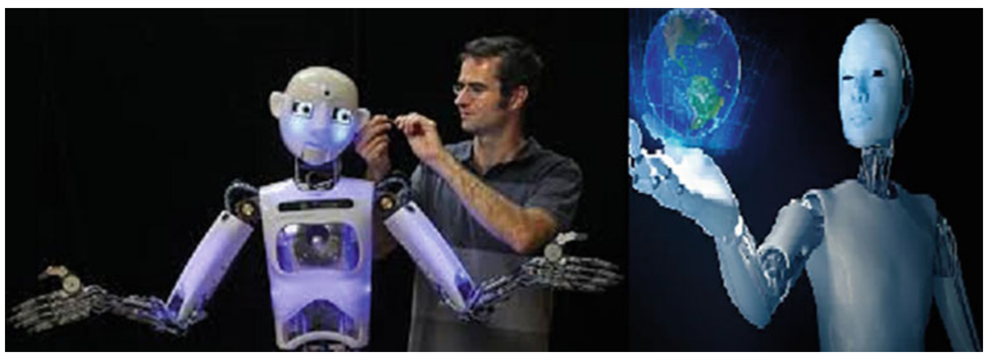


Fig. 2 Human to Robotics

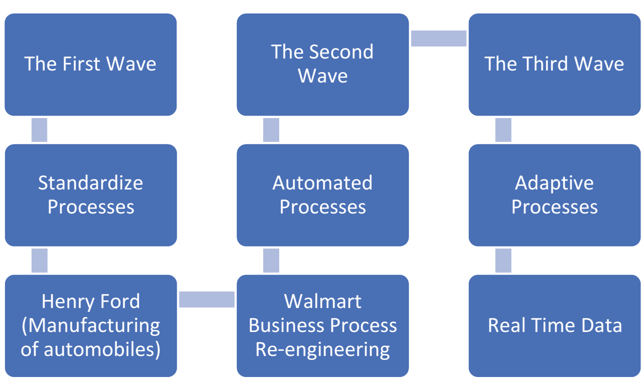


Fig. 3 Advancement in AI

2 Role of Robotics and Automation in Industry 4.0

It is the era by which organizations are automating many processes, making them more efficient and resulting in collaboration of people and machine. Competitiveness in today's business environment is increasing day by day. It is important to take smarter decisions at right time which gives the requirement of more intelligent systems to take smart decisions. Machines in the form of robots from decades are used to perform dedicated tasks in manufacturing processes whereas human in collaboration are assigned predefined tasks such as Inspecting the quality of product and to discard the one with some defects. Robots play an important role in modern industry that can complete their tasks intelligently, with their focus on safety, flexibility and collaborative. In the next few years our society will be different from today. The main technologies are Artificial Intelligence and Robotics Industry. Robotics and industrial automation has completely changed the production and manufacturing phase. Both are working in implementing automation to increase production and hence the economy. The Fig. 4 shows the future of AI and robotics, where a robotic arm is exposed in comparison with human arm.

With the advancement of AI and ML software, traditional industrial Robotics has changed into a new type of collaborative Robot; with the ability to sense their environment, comprehend, act and learn. This has also changed the work Environment where many of the processes has changed to self-adapting processes. This enable the organization to easily deal with the demand of customized orders. The advances in information

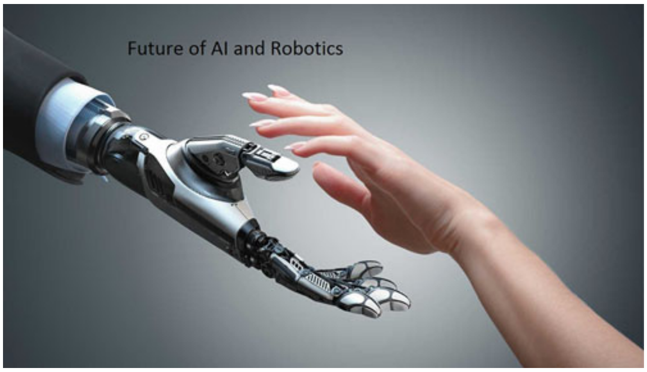


Fig. 4 Future of AI and Robotics

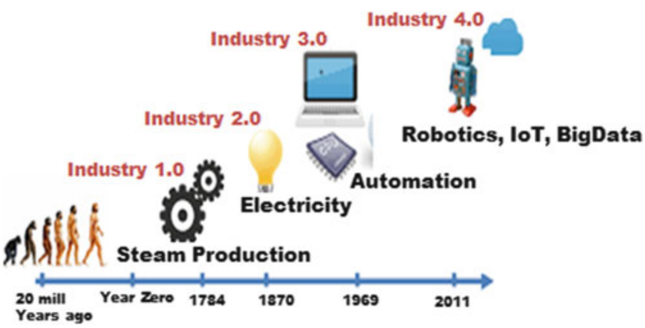


Fig. 5 Industry 1.0 to Industry 4.0

technology like big data, artificial intelligence and cloud change the use and design of robots in the industry. Advancement in these fields has brought changes not only in the field of Manufacturing but also in the area of sales and Marketing for e.g. drone designed and build by Autodesk has made possible the faster delivery at customer doorstep [2]. Robotics brings several engineering areas and skills together. Journey from Industry 1.0 to Industry 4.0 is so big. First industrial revolution started with steam engine and production in eighteenth century. Second Industry revolution started in nineteenth century with use of electricity. Third industry revolution started in 70 in twentieth Century with use of computers. Now we are implementing fourth Industrial revolution so industry 4.0 using Robotics, IOT and Big data as shown in Fig. 5.

Industry 4.0 also known as digital industrial technology; is completely a new phase in Market Revolution in which focus is on Machine Learning, Automation, Robotics and Real time data. Robotics is part of the Industry 4.0 which is the market for smart machines, including expert systems, autonomous robots and digital assistants. According to a recent report from Technavio Research 'Robotics' is growing, day by day in large part because of the rise of Industry 4.0. The aim of Industry 4.0 in Robotics is mainly to develop a smart industry in which products can find their own way through production and can establish alternatives in case of any disturbances, as a technological basis serving "Internet of Things". Automation or Intelligent factory as shown in Fig. 6; means big data, robotics, high end IOT chips and in which everything is connected wirelessly. Ability is to communicate with each other and have ability to control each other.

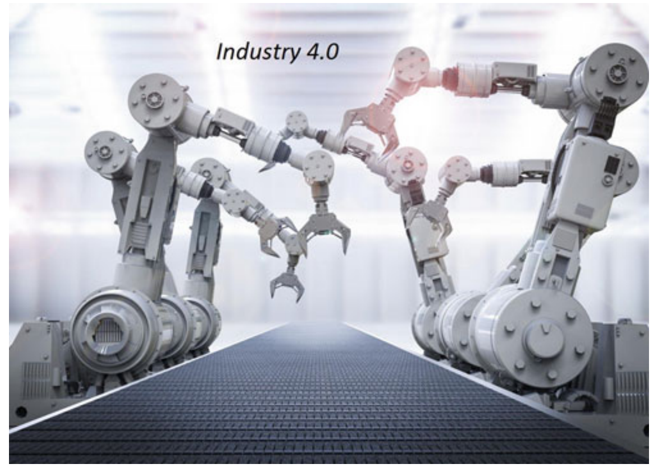


Fig. 6 Robotics and Industry 4.0

The Global competition is increasing day by day due to which market is changing constantly. Customer requirements are bringing new challenges for manufactures and will affect every crucial decision. It is very difficult for the manufacturer to compete in market using old methods because customer wants customize and latest product at low price in fixed deadline. It is impossible to satisfy everyone because it will be complicated and expensive too. Industry 4.0 is an initiative to increase the industrial digitization led by German Government [3]. Today's business environment increasing the use of internet-based digital technologies in production. The development of new technologies like ICT technologies, sensor and their application in robotic technology leads to the development of new robots that can work with the workers. Robotics is the foundations of the fourth industrial revolution. Robots increases productivity, they use sensors and actuators to produce accurate and strong data, but the main fact is no robot has any future unless it is integrated in to network system based on latest technologies. "Smart factory" are future and evidence suggest that future factories will be fully automated and robotized. These factories will become a highly efficient manufacturing location, with machines at different production stages and logistics systems that permanently exchange information without human interference so much [4]. If this vision is to become reality and if industrial production is to become considerably more efficient, we will need to see further technological innovations. Technological progress is visible at many levels even today. Modern production plants are highly flexible. Flexible automation solutions enable tailor-made production, which helps to meet the ever more sophisticated customer and consumer needs.

Fig. 7 Robotics in manufacturing

Mass customization is one of the key goals of the Industry 4.0 and is no longer in its infancy in many different sectors, including textiles, shoes, furniture, clocks or jewellery. Production efficiency is also increased by component management networks. In addition, modern industrial production outfits utilize up-to-date image processing systems for quality management purposes [5].

Automation and robotization also affect people's working lives and fundamentally changing the workplace. Robots are becoming more independent, cooperative, and flexible. Eventually, they will work with humans and interact with one another and will learn from them. These less cost robots will have a greater range of capabilities than those robots which are used in manufacturing today as shown in Fig. 7.

In Industry 4.0 computers and robotics come in a completely new manner. The uses of robots include many functions: production, logistics, and office management (to distribute documents) and they can be controlled remotely [6]. Various types of robots are used in Industry for different purposes.

Robots can also be used for *Predictive Maintenance* purpose. Based on current data for *Predictive maintenance* purpose this approach is used to detect robot manipulator accuracy errors [7]. Machine downtime problem with the equipment can be identified and resolved using sensors.

Collaborative robots are flexible robots which enable new forms of human machine interaction. 'Cobot' is defined as a computer-controlled robot. Collaborative robots are safer, smarter and smaller and have many advantages as compared to traditional robots. Cobots can be stopped or change their positions if anyone applies abnormal force or they came in contact of human. Industrial robots are costly. It is not possible for everyone to afford it. Cobots are light weight, affordable, easy to program and versatile so they are being deployed at SMEs (Small and Medium Enterprises). There are number of industrial robots models which are used. Some of them are shown in Fig. 8. Models differ from each other in payload capacity, distance to reach object and number of axis to travel. Using Robotics and AIED applications there will be some educational cobots who will assist teachers in classrooms using sensors who will help students in gaining more advance concept and will help in data Mining [8]. Main applications of Industrial Robots are pick and place, painting, ironing, welding, testing and product inspection.

Making good products is necessary for the success of a manufacturing projects, but it is not only enough to sustain business and gain Profit. Production costs must be low for a suitable margin. This can be achieved by increasingly improving the efficiency of a manufacturing system. Automation is necessary for that. Automation plays an important role in any factory for manufacturer on their way to Industry 4.0 implementation. Automation provides a boost for industrial automation. Manufacturing systems are designed keeping long term profit in mind. If manufacturers want to be competitive in market, they have to improve both products and the production systems continuously.

Several robots have been introduced with the latest technology to be the pioneer in Industry 4.0. 'Kuka LBR iiwa' is a lightweight robot for industrial applications that is designed for safe close cooperation between human and robot on highly sensitive tasks. 'Kuka LBR iiwa' is Industrial Robot designed for close cooperation between human and robot on highly sensitive tasks. 'Iiwa' stands for intelligent industrial work assistant can learn from its human colleagues and can independently check, optimize, and document the results of its own work while connected to the cloud [9].

The mobile robots are collaborative and the purpose of designing is to design to work safely with human side. Mobile robots use sensors, software and some gear to find

Fig. 8 Industrial robots models

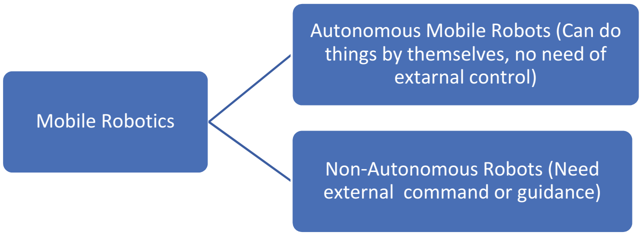


Fig. 9 Types of mobile robots

their surroundings. There are two types of mobile robotics: Autonomous and Non-Autonomous as shown in Fig. 9.

Practically, majority of robots are the semi-autonomous robots. All robots are autonomous to several degree of functionality. But they need commands for special cases either from some external control system or from some human expert.

Autonomous Mobile Robots: These mobile robots do not need external guidance and can explore their environment on their own. Some of the popular autonomous robots are Pet Robots, Game Bot, Delivery robot, Space Robots etc.

Non-autonomous mobile robots: These mobile robots need some guidance system to move. These are also known as controlled robots. For Example, a car manufacturing robot knows how to place the part in assembly line but need guidance to know exactly when and where to fix that part in assembly line.

However, few mobile robotics is important today as companies look at how to utilize artificial intelligence and machine learning. For example, Alexa and other virtual tools that are stationary rather than robotic, mobile robots are in but are not in consumer offering [10]. For narrow spaces and crowded environments Omnidirectional wheels are used for wheeled mobile robots, using these Robot will go on a straight path from one location to another without rotating first [11].

Bosch also introduces the APAS family robot system which includes APAS assistant, APAS inspector, and APAS base for an agile and flexible production concepts based on quickly and easily retooled production systems [10].

The APAS assistant mobile (as shown in Fig. 10) is a collaborating mobile robot used in the Smart Factories for flexible use. These Robots can adapt different tasks and be used independent of location. These Robots are highly Robust and are easy to handle. As ASPS Robots are equipped with safety concept so when a collision occurs, the APAS assistant mobile stops—before any contact. As automation component these are suitable for mechanical engineers [12].

As a collaborative robot, the APAS assistant inline is a good component for efficient planning production, these are cost effective and require very less space. APAS assistant inline can be used in many ways.

Fig. 10 APAS assistant mobile

APAS Assistant Inline for Fanuc Programmers
It is equipped with a Fanuc LR Mate 200 iD/7L, the standard version is programmed using the classic Fanuc control. The system is characterized by its price aptitude.

APAS Assistant Inline Plus for PLC Programmers
In this, the robot is delivered with the Bosch Control plus platform. This is a control system with a function library and having number of apps and software services, all are using the latest technologies. All processes are developed in an object-oriented modern development environment and can be implemented in a structured manner.

APAS Assistant Inline for KUKA Programmers
Based on KUKA Agilus, KR 10 R1100-2, the robot is programmed using the classic KUKA control. The high load capacity and the long reach make the APAS assistant inline on KUKA basis a valuable production assistant for monotonous unfavorable tasks.

Human-robot collaboration plays an important role in Industry 4.0. In human-robot collaboration, the robot assists the human operator and work hand in hand. It is not easy to replace humans in this also machines do not replace humans but relives him of tedious tasks like the lifting of heavy loads, putting heavy parts from one place to another. The aim behind collaboration is to combine the skills of humans and machines together so achieve more, precise and accurate output. Human robot collaboration is future for industries in manufacturing and production. Main advantage of Human robot collaboration is flexibility in production, less risks and high-quality performance. Using four components of gesture recognition like gesture identification, gesture tracking, gesture classification and sensor technologies a model is proposed in human-robot collaborative manufacturing [13]. FUNAC and KUKA are other leading global robot manufacturer. They built collaborative robots. Collaborative robots with a connectivity of AI and machine learning results in creation of intelligent system for industrial robots. These robots can work with humans. Moreover, earlier traditional robots require extensive programming for adding new capabilities. But in collaborative robot using AI and machine learning can easily be programmed to add new capabilities. 'KuKa' has developed robots that are approved for human robot collaboration. 'KUKA' LBR are mobile rendered and can perform different flexible tasks using mobile platforms as KUKA Fellow. KUKA LBR iisy and KUKA LBR iiwa use high performance sensor and latest technologies which provide a solution in production.

A collaborative robot (COBOT) is a robot that can learn many tasks so it can help humans in many ways. The main purpose of collaborative robot is the action of working with someone to create or produce something [14]. At a BMW car plant in South Carolina engineers found that how a lightweight robot arm can be fitted with door panel and help in lifting door panel [15].

There are mainly four types of collaborative robots. These are classified based on their safety and programming features. Moreover, classification is done based on how they provide abstraction to human workers to encounter with potentially dangerous tasks. Each of these robots is also differ in the technological way to provide safe operating space for humans. Thus, they are best suited for different environments. COBOTS are used in Manufacturing industry and healthcare. The main collaborative robot manufacturers include, KUKA, Rethink Robotics and Franka.

Major Types of Collaborative Robots

According to ISO 10218 part 1 and part 2 four types of collaborative robots are as listed below:

1. Safety Monitored Stop
2. Speed and Separation
3. Power and Force Limiting
4. Hand Guiding

The details of each is discussed as follows:

1. **Safety Monitored Stop** collaborative robots are designed for the applications where minimum interaction is required between robots and human workers. Ideally, these types of robots are designed with a series of sensors that stop robotic operations as soon as a human enters the work environment.
2. **Speed and Separation** robots uses more advanced vision system as compared to safety monitored stop collaborative robots. The advanced vision system enables collaborative robots to identify the human worker and accordingly slows down the operations. Moreover, as the human worker gets too closer; the collaborative robots stop the operations immediately.
3. **Power and Force Limiting** collaborative robots are designed with a series of intelligent collision sensors and are built with rounded corners instead of sharped corners. The intelligent collision sensors quickly detect the human workers contact and stop operation. It also has a feature force limitation that ensures no injury even in case of any collision.
4. **Hand Guiding** As the name suggest these Robots can simply be re-programmed for new tasks by an operator itself through guiding collaborative robot arm by hand. This allow quick reprogramming with minimum time and also reduce the requirement of specialized programmer with robotic knowledge

The adoption of Industry 4.0 will introduce new products and services and it will allow manufacturers to create new jobs to meet the higher demand which will result in the growth of existing markets.

The key principles of Industry 4.0 are Automation, Digitization, and Data collection [16]. By using these principles manufacturers can improve efficiencies while streamlining costs and maintaining a quality customer experience. Essentra components are one of many manufacturers just starting out on their Industry 4.0 journey.

Automation and Industry 4.0 together will help and support in longevity of a business. It is a golden time for the manufacturing industry and businesses must respond to these new technological developments and ensure they are meeting the developing demands of their customers.

Robotics has transformed the whole world in two different phases. In first phase electric machines were used to avoid repetitive tasks robots like these were used in car manufacturing. In second phase industrial robots are used and their usage is seen in automotive industry. Bosch, has infused both Robotics and automation across worldwide. In automotive industry also called Smart Automation where five machines assembly are handled by single robot [17].

Hitachi industry are using artificially intelligent bosses, and they have also announced a robotic warehouse worker which can handle goods with two arms. To increase the productivity, workers have started to take orders from artificial intelligence programs the company says productivity has already increased in the warehouse environment by 8%, compared to one of their non-AI run warehouses [18], and they hope to expand "human and AI cooperation". Autonomous warehouse robots outfitted with AI algorithms are used by Amazon to deliver items to the humans packing boxes. Intelligent bosses have many capabilities like:

- It can monitor and evaluate how a shop floor worker tackles daily problems and provide solutions of these problems with higher efficiency.
- It also has ability to study the changing work environment and response of these to modify work order.

In another example, Loreal company is using RFID (Radio-Frequency Identification) and machine learning techniques. RFID tags uses an alarm if a person reaches too close to a vehicle [19].

Siemens, the Telecommunication and German Company in the company's Princeton, New Jersey lab are creating spider-like robots that are using AI to 3D-print structures [20].

Arm that learns according to research done by Shohai hide, chief researcher at preferred N/W. It takes about 8 hours for an arm to become 90% accurate for assembly kind of work in factories. This enable human worker to do other more complex tasks that generally require judgements.

Rethink Robotics, founded by Robotics and AI pioneer equipped the Robots with more precise sensors and allow robots to recognize objects when they come in proximity, so to avoid collision. The Robotic arm with sensors can work in collaboration with human in any assembly factory. For example, in a car assembly factory if a worker needs to put an interior panel on one of the car doors; a robot can help him by lift the panel and place it into the position. This allow the worker to just do the fine adjustments and check for the accurate positioning that too without any fear. Thus, robots and human can work in collaboration to their strengths. Similarly, at **Fraunhoter Institute of Material Flow and Logistics** where in car plants self-adapting assembly lines were tested. These embedded sensors create assembly lines that can modify steps in order to fit the demands and results with highly customizable cars. Thus, has changed the assembly line designed to make one kind of car to adapt the designs as needed.

Thus, process engineers don't require to reconfigure the assembly line for each change in demand rather spend their valuable time for more creative tasks and thus improve the overall efficiencies.

Unmanned Vehicles at BHP Bilito Ltd, Vehicles are equipped with IR sensors and telescopic zoom features. This make them suitable to use for problems with safety features. These IR sensors Robots [21] make sure that a blast zone is clear of detonation.

Boeing's Echo Voyager is another robot that is deep sea robot. It has various functions like collecting under water samples, inspect under water infrastructure. It can draw maps of the ocean floor and help in explaining oil and gas resources. Unlike other remote controlled unmanned underwater vehicles that stay close to their ships for support and water this echo voyager [22] is using advanced robotic system and can be autonomously operated for a month.

Fig. 11 Nike Spike Shoes for Sprinter

Robots can do wonder in **product design** too. It is a challenge for many companies to use AI and big data to design the product that meet the exact need of targeted customer. **Nike** was having a challenge to design the spike shoes; where, a stiff spike plate was better to give the runner support to push off against. But the spike plates were heavy resulting in sprinter down. With, the help of robotics software [23], the task is accomplished with both stiffness and lightness shoe design as shown in Fig. 11. Human designer can accomplish the same task after number of iterations even though it would not be so optimized as after the use of robotics software.

3 Technological Requirements for Robotics

Robotics technologies are a mixture of computer science with electrical and mechanical engineering. This enables to design and create automated intelligent machines, which is the requirement of today's industry. Robots are automated systems that are designed and build to assist the various processes in the industry without direct human intervention [24]. Robots are now a day required in various industries related to manufacturing, defense, aerospace automated systems and everyday lives. Because of the demand of robots in diverse applications, a blend of technologies is required; mainly to design and upgrade the robotics systems and to maintain and repair them.

Robots are automated machines that intermingle with the real world by means of sensors. The advancement in technologies has made it possible to fabricate sensors capable of acting just like human organs that enable robot to act like a human being. These sensors are designed and created to accomplish the functionalities of various human organs like eyes, ears and nose etc. Thus, as the organs are important in humans so the sensors in robots or robotics technologies [25].

However, the design and applications of robots varies with the different requirements and so the technologies required during their designing, manufacturing and maintaining processes. Technologies varies from artificial intelligence, machine learning, perception, speech recognition, image processing and sensing, dealing with microphones and wireless signals and last but not the least gesture recognition. But without sensors robots' various functionalities are not possible.

Now days in Industry 4.0 robots are not only used in industrial activities but also have become a significant part of military and civil applications, entertainment industry like media, advertisement and movies [26]. For example, robotic arm plays vital role in various applications such as, assembly, welding and painting application and to shoot the amazing movie scenes which are not possible by carrying the camera and other equipment using the normal arrangement.

Industrial robots necessitate several sensors to simulate a variety of capabilities that human being possess. These sensors enable robot to see, hear, touch and move like humans. Thus, is responsible for environmental feedback regarding surroundings and terrain.

In self- driving vehicles various sensors that are essential for accurate working comprised of distance, object detection, vision and proximity sensors. These further require camera, IR, sonar, ultrasound, radar and lidar.

An integration of various sensors empowers industrial robot to determine size, identify an object and determine its proximity. Moreover, wireless sensors devices (such as RFID) support to identify codes and other important information. For the feature to pick small and lift heavy objects it requires Force sensors. In industrial application where robots need to sense the force required to be applied on parts of some assembly shaft, it is essential to measure and control rotational forces. Torque sensors fulfill this requisite.

Similarly, in industry where need is to govern the temperature in order to avoid potentially- harmful heat sources from environment, temperature sensors plays vital role.

Humanoid robots with AI algorithms can be useful for future distant space exploration missions. Atlas is a 183 cm (6-feet) tall, bipedal humanoid robot, designed for a variety of search-and-rescue tasks for outdoor, rough terrains. It has an articulated sensor [27] head that includes stereo cameras and a laser range finder.

The various sensors used in robotics are as follows:

Biosensors

Biosensors are used in medical applications. These are used to detect the presence of various chemicals by using a sample of living creature and of biological particles. The application those uses biosensors includes blood glucose monitors, DNA biosensors etc.

Raindrops Sensors

Raindrop sensors are used in weather forecasting and analysis applications. After detecting the rain and weather conditions, these sensors convert the information thus obtained into number of reference signals and further to analogue output.

Multi-axis Force Torque Sensors

As the name specifies this sensor is used to sense force and torque applied to various axis of a tool by just fitting it on the wrist of the robot. Such sensors are fitted onto the wrist of robots to detect forces and torques that are applied to the tool.

Optoelectronic Torque Sensors

The collaborative applications require safe and more effective human-machine interactions. In these applications optoelectronic torque sensors are used. These sensors have less than one microvolt of noise even in low-torque range and have capability of sensing accuracy up to 0.01%. The principles applied in these sensors guarantees about the insensitivity to vibrations and to deterioration.

Inertial Sensors

Consumer products like computers, mobile phones, digital games and advanced digital cameras necessitate motion sensing mechanism to provide various facilities. Inertial sensors are employed in a wide range of such consumer products. Inertial sensors are available in various types depending upon the need of applications. For example, Industrial-grade inertial sensor contrived by LORD MicroStrain provide a facility to measure tri-axial inertial and to compute attitude and navigation solution.

Sound Sensors

To enable a robot to receive and process the voice commands, sound sensing is essential. Thus, sound sensors are required for voice assistant applications like Google, Alexa and Siri.

Emotion Sensors

Many of the times humans interact with each other or talk to other depending upon the mood of the other person, judged by just evaluating the facial expressions. Which includes the mood detection, person identification etc. robots can perform the same by using emotion sensors. Emotion sensors when plug-in to robots make it enable to detect faces and to evaluate mood depending upon the facial expressions. For example, B5T HVC sensor from Omron Electronics is a human vision component trained to recognize faces with speed and accuracy.

Grip Sensors
Robotics Surgery gradually has become the new challenge in Medical Sciences. This has become possible only by the use of Grip sensors. RoboTouch sensor technology has given this era in robotics that allows robot to sense the touch. Robotouch's capacitive tactile technology has enabled industrial and consumer robots to sense the touch and to grip with great optimized accuracy. This has also proven to be ideal for OEM integration in robotics gripper. These Grip sensors comprise of sensors that can either directly be used on hand or built into a glove [28]. These sensors are further encompassing of multiple sensing pads, placed on anatomic segments of hands. Gaps between the sensing are kept intelligently to allow hand joints move freely and to measure grip computation with higher accuracy.

4 Application of Robotics in Industry 4.0

The Industrial Revolution will add a new standard of living for coming centuries and swill increase the economic growth of world. In Industry 4.0, robots and humans will work hand in hand, using smart sensor human-machine interfaces on interlinking tasks. Autonomous robots are best example across manufacturing industries. In consumer driven world main aim is to provide more values in shorter time to consumers. Any defective part that hits the market can bear serious consequences to the credibility and sales of the enterprise.

There are many applications of Robotics to Industry 4.0 discussed as follows:

1. **In Manufacturing**: There are many challenges related to labours. Main are running cost and lack of skills. One solution to this problem is Automation. For instance, some automotive work currently requires heavy lifting in that case a robotic device can be used to relieve a worker from physically demanding tasks. For example, a robot could lift a car's interior-finishing elements. Experts claim that machines are to take over tasks that are too physically difficult or dangerous for humans, like installing hybrid batteries that weigh more than 100 kilos. Embodiment of Industry 4.0. Is the "Smart factory" —A smart factory is a manufacturing plant that's not only automated but all the equipment's are digitally interconnected within one system [29]. Such a factory enables the monitoring and controlling of all the physical processes in real time. Industrial robots are used with the current technical innovation to promote the industry. Robot-based inspection systems are used in vision systems, allowing for flaw detection in various parts, and guaranteeing the correct part assembly. The vision system inspects and finds a part accurately.
2. **Autonomous Vehicles**: As the population is increasing and the number of road accidents are increasing day by day. The concern is how to reduce the number of accidents on road. Autonomous vehicles are using in many fields like manufacturing, mining, agriculture, logistics, transport etc. [30]. Automated guided vehicle (AGVs) are used in to transport material to a warehouse. In a fourth industrial revolution, AGVs are shifting from automation towards intelligence. Using a Wi-Fi module, laser navigation, and latest technologies, an AGV manufacturer has created an intelligent parking robot that can lift and park a car in just 120 seconds.
3. **In Health Care**: Robotics is used in healthcare (as shown in Fig. 12) to compound drugs, which helps to improve operator safety, cost and quality. Before any physical action takes place the fusion of emerging technologies will allow you to train operators and optimise production. Having error free robots means the robots which perform erring tasks such as aseptic fill finish, where human error can ruin an expensive batch of drugs, i*s good*. AURA Robot designed starting from a traditional robot, in which standard state machine are still present, but automatic and remote modes are subdivided in others three non selectable states: when the robot is in automatic or remote mode, the laser scanner**.** Robots are Performing accurate surgery and making them less costly for their patients. Another Major advantage of robots is that they can work with chemicals that are harmful to humans as well as provide a greater efficiency in operations [31].
4. **In Packaging**: A new generation of robotic systems and improvements in data flow means package production can integrate and connect key processes packaging production requires design, production, distribution, maintenance—all into a single integrated approach, rather than relying on separate pieces of automation.
   The most important impacts of latest robotic platforms will be felt in converting and distribution.
   Food packaging is one of the robotic applications which is used in the food industry. Robots can be used in

Fig. 12 In healthcare

Fig. 13 Robots used in Food Packaging

packaging of food, cakes, creams, lettuce and milk as shown in Fig. 13. Robot in Food Packaging Industry will increase productivity and it will be easy to handle products, pick and place items, packing and palletizing will become efficient [32]. Robots are programmed to fill the exact amount of food in packaging modules, whereas, same is not possible if human employee are assigned the job. Thus, efficiency and productivity both will increase.

5. **In Mining**: Mining Industry is also using robotics and current technology. Robot-operated drills are used to drilling deeper in earth. Robots can be used to get detailed information inside mine. Autonomous vehicles combined with drones are used to inspect oil and gas lines in disputable areas to use autonomous mining equipment. Indeed, Schlumberger is currently using an autonomous underwater vehicle to use autonomous underwater vehicle to inspect sub-sea conditions requiring no local team support. Similarly, Submersible ROV (Remote Operational vehicles) previously were lowered and supported by a umbilical cord from a mother ship which supplies power and control signal, but Autonomous ROVs are self-powered. Self-driving vehicles are also used in mined industry. Rio Tinto, world's largest mining firm [33] using more than 80 trucks at its iron one mines in Western Australia.
6. **Military and Public safety Industry**: due to rapid change in technology Military Industry and Public Safety Industry also changed. Drones are used in Military Industry and robots are used in battlefield support, conducting surveys and used for guard duty as shown in Fig. 14. These robots (drones) are equipped with adequate amount of battel material and is able to sense the environment, thus can attack.
   In public safety industry remote controlled drones [34] are used to provide real time analysis of situation and monitoring dangerous situations. Robots are also used for monitoring risk assessment.
7. **Supermarket and Malls**: Wallmart are using automated technology and robots to order their products online when the products are out of stock and robot mopping up floors. The machines are using sensors to scan for people [35]. Robots can be used as in-store shopping assistants which help customers to find their products, retrieve their products which are placed on shelves in which customer is unable to reach as shown in Fig. 15.

Fig. 14 Robots in Military

8. **Agriculture**: In agriculture Self driving tractors are used which provides guidance on fertilizer application sensor used can tell the different data on soil conditions and how to maintain planted crops as shown in Fig. 16
9. **3D Printing and Furniture World**: Ashley furniture is using robotics and 3-D technology to expand furniture production in a low labor market; instead of collecting the many small parts necessary to equip robots with the right tools to make a certain kind of furniture, Ashley [36] has created those parts in-house in real time and upgraded to 3D Printing.
10. **Robots in Music**: Georgia Institute of Technology has built a four-armed robot called 'Shimon' is able to listen to music. It can further extemporize and play with human musician in concert [37]. Gil Weinberg, the lead researcher at Georgia Tech's Center for music technology and his team has demonstrated their 12 years research work as 'Shimon'. Their main aim was to augment the inventive capabilities of human with robotics. Shimon thus built can learn from music theory and musical notes and styles. It can add element to musical performances and can play chord structure which is impossible for human to play.

5 Challenges in Robotics Automation

There are many challenges to robotic automation.

1. **Employee Skill set and Training**: Proper certifications, training and education is required for any new system installed. For robotic environment proper experience

Fig. 15 Robots in supermarket

Fig. 16 Robots in agriculture

and training is required so employees will have to be hired who have good knowledge and certification in this field.

2. **Safety Measures**: Safety is the foremost issue. Manufacturer must ensure compliance before robots get installed and provide a safe environment to their workers.
3. **Budgeting**: There's lot of upfront investment associated with robots, although prices are dropping. It is not possible for everyone to spend too much.
4. **Managing Product Workflow**: Product workflow is important. Productivity depends on orientation and movement of parts, speed etc.
5. **Demand**: Increase in smart technologies will increase demand for complex products. Manufacturers said that today car buyer wants car model built to his own specification**.**
6. **Balance Repetition and automation**: With variation in demand it is challenge for manufacturer to balance repetition and automation and maintain a high-quality product. In production it is important to check that every tool operates in right way and at right time.

6 Pros of Robotics Automation

1. ***Decreased Production Costs***: with use of Robotics speed increases which impact production.
2. ***No time waste***: Robots will work in speed without break, sleep and will give better output than human worker
3. **Reliability and Quality improves**: In industry precision and accuracy plays an important role. Some products are manufactured with same process and same specification every time. So robotics will improve precision and accuracy.
4. **Reduced waste**: Robots work with accuracy and it will reduce the cost on waste.
5. **Increased Safety**: Some parts are dangerous to work or pick upon. Safety will be increased using this
6. **Savings**: Quality and customer satisfaction plays a significant role. Increase in both will return more customer and more business.
7. **Multiple Application**: robots can perform multiple operation simultaneously which will affect business.

7 Conclusion

Industry 4.0 is known as Industrial Internet of Things (fourth Industrial Revolution). Here, all the equipment, devices and computers are connected in manufacturing processes. It provides an environment that is rich enough for big data analysis and self-correcting procedures with an open era for many other possibilities. With the help of sensors, smart machines and products can communicate and learn from each other and all this together is leading to Intelligent factories. Robotics and human cooperation in Industry of the future will help in taking complex decisions in advance possible by understanding the risk in advance Another key feature is their ability to control cooperatively each other. Now the most important question is whether the Robotics will replace human or take all job away from humans. Humans have great knowledge they can do precision handling and have sense of touch. Robots can do repeated task with efficiency, speed and reliability. Industry 4.0 and robotic technology both are our future and together results in customer satisfaction, efficiency and reliability of product. Then the answer is that it is not possible because for robotics to be fully functional it requires installation of navigation devices, elevators, trained people, automatic doors etc. Further, it is not possible for everyone to afford this. Whole process is too much costly. So, robotics will not replace human contact 100%. The applications of Industry 4.0 and Robotic technologies are also elaborated in this chapter.

References

1. https://skymind.ai/wiki/ai-vs-machine-learning-vs-deep-learning
2. "Industry 4.0: the fourth industrial revolution – guide to Industrie", https://www.i-scoop.eu/industry-4-0/.
3. Albers, A., Gladysz, B., Pinner, T., Butenko, V., & Stürmlinger, T. (2016). Procedure for Defining the System of Objectives in the Initial Phase of an Industry 4.0 Project Focusing on Intelligent Quality Control Systems. Procedia CIRP, 52, 262-267
4. Bartodziej, Christoph Jan (2017), The Concept Industry 4.0 An Empirical Analysis of Technologies and Applications in Production Logistics
5. Batista, N. C., Melício, R., & Mendes, V. M. F. (2017). Services enabler architecture for smart grid and smart living services providers under industry 4.0. Energy and Buildings, 141, 16-27.
6. Bartodziej, Christoph Jan (2017), The Concept Industry 4.0 An Empirical Analysis of Technologies and Applications in Production Logistics
7. Tawfik Borgi, Adel Hidri, Benjamin Neef, Mohamed Saber Naceu, "Data analysis for Predictive Maintainence of Industial robots", 2017 International Conference on Advanced Systems and Electric Technologies (IC_ASET)
8. Timms, M. J. (2016). Letting artificial intelligence in education out of the box: educational cobots and smart classrooms. International Journal of Artificial Intelligence in Education, 26(2), 701-712.
9. Andreas Bauer. 2016. KUKA LBR Iiwa. Augsburg: Kuka RoboterGmbH.
10. Liu, W., Zeng, L., & Feng, D. (2016, August). Apas: an application aware hybrid storage system combining ssds and swds. In 2016 IEEE International Conference on Networking, Architecture and Storage (NAS) (pp. 1-4). IEEE.
11. Kanjanawanishkul, K. (2015). Omnidirectional wheeled mobile robots: wheel types and practical applications. International Journal of Advanced Mechatronic Systems, 6(6), 289-302.
12. Robert Bosch GmbH. 2015. Changeable Automation With TheAPAS family. Stuttgart
13. Liu, H., & Wang, L. (2018). Gesture recognition for human-robot collaboration: A review. International Journal of Industrial Ergonomics, 68, 355-367.
14. Saito, T., & Ikeda, H. (2007). Development of normally closed type of magnetorheological clutch and its application to safe torque control system of human-collaborative robot. In Electrorheological Fluids And Magnetorheological Suspensions (pp. 557-562).
15. https://roboticsandautomationnews.com/2017/03/04/bmw-shows-off-its-smart-factory-technologies-at-its-plants-worldwide/11696/
16. Givehchi, O., Trsek, H., & Jasperneite, J. (2013, September). Cloud computing for industrial automation systems—A comprehensive overview. In Emerging Technologies & Factory Automation (ETFA), 2013 IEEE 18th Conference on (pp. 1-4). IEEE.
17. http://www.oemupdate.com/technology/top-robotic-applications-in-automotive-industry/
18. https://www.popsci.com/hitachi-hires-artificial-intelligence-bosses-for-their-warehouses
19. https://www.rfidjournal.com/articles/view?12083
20. https://qz.com/672708/siemens-is-building-a-swarm-of-robot-spiders-to-3d-print-objects-together/
21. https://wiprodigital.com/2018/11/13/the-rise-of-industrial-autonomous-vehicles/
22. https://newatlas.com/boeing-echo-voyager-trials/50010/
23. Margaret Rhodes, "Check out Nike's Crazy New Machine-Designed Track Shoe", July 20, 2016 https://www.wired.com/2016/07/check-nikes-crazy-new-machine-designed-track-shoe/
24. Batista, N. C., Melício, R., & Mendes, V. M. F. (2017). Services enabler architecture for smart grid and smart living services providers under industry 4.0. Energy and Buildings, 141, 16-27.
25. Erol, S., Jäger, A., Hold, P., Ott, K., & Sihn, W. (2016). Tangible Industry 4.0: a scenario-based approach to learning for the future of production. Procedia CIRP, 54, 13-18.
26. Gilchrist, A. (2016). Industry 4.0: The Industrial Internet of Things
27. https://www.theverge.com/2013/7/11/4515788/darpa-unveils-6-foot-tall-humanoid-robot-atlas
28. Anne Mandy, Lucy Redhead, Jon Michaelis,: "Measurement of Hand/Handrim Grip Forces in Two Different One Arm Drive Wheelchairs", published online 2014 Jun 19. doi: https://doi.org/10.1155/2014/509898
29. https://eandt.theiet.org/content/sponsored/essentra-the-future-of-automation-and-industry-40/
30. https://wiprodigital.com/2018/11/13/the-rise-of-industrial-autonomous-vehicles/
31. https://compliancenavigator.bsigroup.com/en/medicaldeviceblog/robotics-in-healthcare/
32. https://www.industrialpackaging.com/blog/why-robotic-packaging-automation-is-the-future
33. https://www.nbcnews.cshiom/mach/science/robots-are-replacing-humans-world-s-mines-here-s-why-ncna83163
34. https://www.investopedia.com/articles/markets/011216/4-industries-robots-are-revolutionizing.asp
35. https://edition.cnn.com/2018/12/07/business/walmart-robot-janitors-dotcom-store/index.html
36. https://www.zdnet.com/article/3d-printing-and-robots-power-largest-furniture-maker-in-the-world/
37. A four-armed robot can now improvise music as well as human bandmates, Mike Murphy, 23 May, 2016. https://qz.com/689827/moogfest-shimon-music-robot/

Ruchi Goel is working as an Assistant Professor at the Department of Computer science and Engineering, Maharaja Agrasen Institute of Technology, Delhi, India. She has 15+ years of teaching experience. Currently, She is pursuing PhD from DTU (Formerly Delhi College of Engineering). She has done her master's degree from Delhi College of Engineering in 2011. Her research area of interests are software testing, Web Mining, improving software quality. She has published eight research papers in international journals and conferences.

Pooja Gupta is Assistant Professor at Maharaja Agrasen Institute of Technology (MAIT), GGSIPU, New Delhi India. She has 17+ years of teaching experience. She has completed Ph.D. Computer Science and Engineering from JIIT (April–2014) and MTech (CE) from YMCA, Faridabad (MDU, Rohtak) (2006). Her area of interest are Information Retrieval and Data Mining, Machine Learning, Computer Networks. She has published more than 12 papers in international journals and conferences.

Additive Manufacturing: Concepts and Technologies

Pimal Khanpara and Sudeep Tanwar

Abstract

Industry 4.0, the recent industrial uprising, encourages the inclusion of smart manufacturing systems and sophisticated IT. In this fresh motion, additive production (AM) is regarded an important component. An extensive analysis of AM techniques with both its contributions to Industry 4.0 is provided in this paper. The analysis focuses on three key elements of AM: latest progress on material science, operation growth, and design consideration enhancements. The paper's primary goal is to identify and demonstrate its prospective applications of present information (and technological developments) on AM. Industry 4.0 is the modern move toward smart automation of technology. In this current time, the use of Additive Manufacturing's modern abilities in the domain of IT integration plays a major role in the competitiveness of the industrial domain. This paper provides a fundamental understanding of Industry 4.0's role of 3DP technology. As can be seen, there is no uncertainty that 3DP technology is going to contribute to the upcoming significant industrial era. Due to its multifaceted features, time and price savings, Additive Manufacturing performs a significant part in Industry 4.0, being critical to process effectiveness and decreasing entanglement, permitting quick prototyping and extremely decentralized manufacturing procedures. A large number of manufacturing sections are now embracing AM. Future intelligent plants communicate all procedures via the Internet of Things, integrating higher pliability and individualization of production procedures.

Keywords

Additive manufacturing · 3D printing · Smart factory · Industry 4.0 · Smart materials · Computational geometry · Production process

1 Introduction

There is a need to digitize and intelligentize manufacturing procedures for today's industrial sectors. The production sectors are now shifting from mass manufacturing to custom manufacturing. The fast developments in technology and applications for agricultural manufacturing assist to boost efficiency [1, 2].

A manufacturing chain is the method of converting raw materials into commodities. Nevertheless, to transform the accessible funds into products such as architecture, scheduling, production and distribution, many measures are required. Recently, as additive manufacturing (AM) or 3D printing (3DP) technology has altered its measures, it appears that the production chain process has shifted. Customized products with hard geometries can be constructed and printed using additive technology. Therefore, markets can be proffered without needing businesses to reserve or generate products at a high cost [1].

The word Industry 4.0 constitutes the fourth industrial revolution described as a fresh stage of organisation and restrict over the whole product life cycle value chain; it focuses on increasingly individualized client needs. Industry 4.0 is still innovative but a practical idea which involves: Internet of Things (IoT), Cloud-based Manufacturing (CBM), Industrial Internet (II), and Smart Manufacturing (SM). Industry 4.0 is concerned about the rigorous inclusion of people into the manufacturing system to continually enhance and concentrate on value-adding and waste prevention operations [3].

P. Khanpara · S. Tanwar (✉)
Department of Computer Science and Engineering, Institute of Technology, Nirma University, Ahmedabad, India
e-mail: sudeeep.tanwar@nirmauni.ac.in

A. Nayyar, A. Kumar (eds.), *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*,
Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-14544-6_10

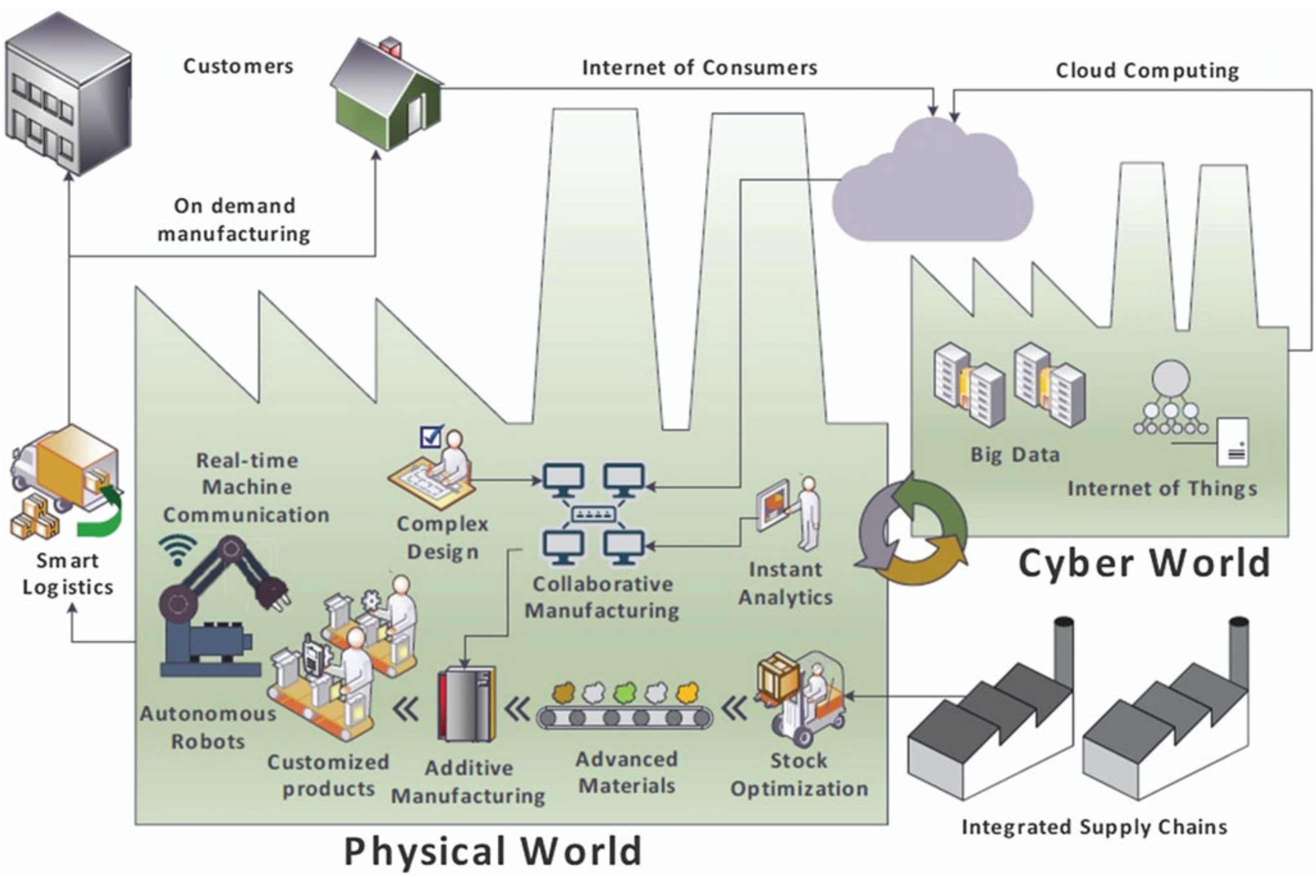


Fig. 1 Illustration of smart factories in Industry 4.0 [5]

The fourth industrial revolution, Industry 4.0 is the latest motion on smart computing technologies. The use of contemporary production abilities in the framework of incorporating fresh data techniques in this fresh age performs a major part in financial competitiveness [4]. As shown in Fig. 1, Industry 4.0 provides profitable cooperation between cyber and physical devices with the aim of constructing intelligent plants by redefining the position of individuals.

The basic virtual world ideas of smart factories include Cloud computing, Internet of Things (IoT), Big Data, etc., while its physical domain involves independent robots and Additive Manufacturing [2, 6–25].

With regard to cyber-physical devices, IoT is defined as the notion of using computer networks or enhanced cellular links to collect data from physical artifacts. The information obtained from the goods, machines or manufacturing lines is a significant quantity of statistical data to be shared and evaluated. Other data sources are layout documents, order of clients, distribution of providers, information linked to inventory and logistics. Overall, this big amount of information is described as Big Data, which in Industry 4.0 is another significant concept. Furthermore, cloud computing, which is linked to the handling of all accessible data, can also be regarded one of the most important concepts in the implied manufacturing environment. All of these cyber techniques assist guarantee that current data is used effectively for potential intelligent manufacturing [2].

On the other side, the capacity of the current production technologies limits the physical portion of the intelligent machines. This makes the AM one of Industry 4.0's essential parts. Because of the need for mass customization in Industry 4.0, it is necessary to develop non-traditional production techniques. Due to its capacity to produce sophisticated items with advanced characteristics (fresh fabrics, forms), AM can thus become a main technology for manufacturing tailored goods. AM is presently being used in multiple sectors such as aviation, biomedicine and production, thanks to enhanced consumer quality [3]. While there are still some questions about its applicability in mass manufacturing, owing to the latest technological advances, the use of AM in the sector is on the increase. It can give a way to substitute standard production methods in the upcoming age as an emerging technique to produce precise and reinforced complex items with enhanced production velocity.

Existing production systems' capability confines the intelligent factories' physical portion. Due to the need for mass customization in Industry 4.0, fresh non-conventional production techniques are constantly being created. AM is

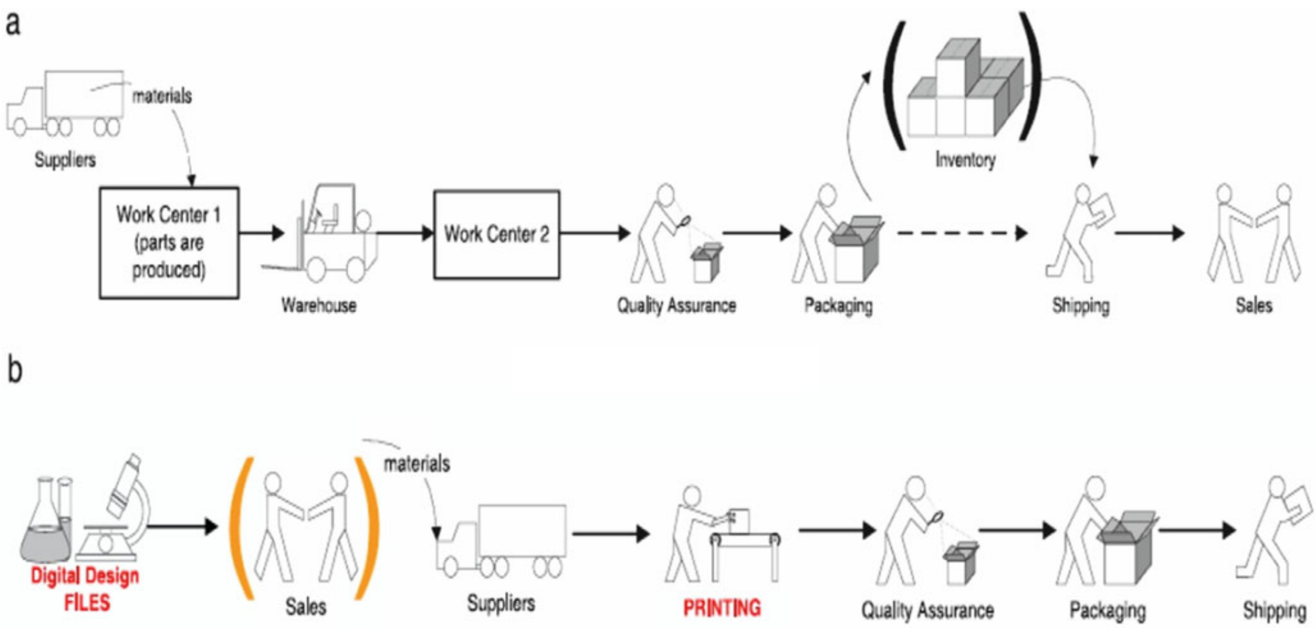


Fig. 2 Classic and 3DP procedure [27]. (**a**) The classic procedure. (**b**) The 3D printing procedure

considered a main technology for production of custom products [26] due to its capacity to produce sophisticated items with advanced characteristics. Figure 2 illustrates a comparison between standard business method and 3DP method:

In comparison of conventional manufacturing and additive manufacturing, the overall benefits of additive manufacturing are the product development and growth skills. Though there are some constraints, businesses are increasingly using AM to get advantage of the many prospective advantages such as complexity-free production. In traditional production [28], a straight connection exists between complexity and production expenses.

High production and tool-making expenses often significantly restrict designs meant for traditional manufacturing. The higher design flexibility through AM makes it possible to integrate the assembly of components into a single unit, thus lowering the necessary configuration job and expenses. In addition, implementation capacities [26] do not need to be compromised.

3DP emerges as a technology that allows for a broad range of fresh applications. Basically, the accessible equipment, manufacturing velocity and resolution of the 3DP procedures should be regarded for each particular implementation [29]. Nowadays, there are devices that enable the production of 3D forms by diverse methods: extruder (fused filament), chemical agent (binder) or laser (sintering/fusion), technically recognized as additive manufacturing (AM), with several benefits [30].

Industry 4.0 is the latest step towards technology intelligent automation. In this current time, the use of AM's advanced IT inclusion abilities plays a significant part in the industrial economy's competitiveness. In this sense, this paper tries to offer the fundamental knowledge Industry 4.0 and 3DP technology.

This paper reviews Industry 4.0's latest physical literature to assist AM scientists classify/sort basic expertise in the sector. AM is the primary range of this paper because of its important position in Industry 4.0. The paper is organized as follows: first, the enhancement in material science will be addressed. In the following section, AM's novel methods are described in detail, specifically metal additive processes and hybrid procedures, while the next chapter describes AM's design associated problems. Lastly, the last segments contain potential AM-related expectations and findings.

2 Materials

Materials are essential for scientific comprehension AM technology advancements. New materials appropriate for 3D printing applications are of great concern to researchers in this sector. Although there are a big amount of metal/polymer components are accessible for AM [26], as demonstrated in Fig. 3, certain products attract attention in this field. Therefore, it is necessary to discuss in detail the characteristics of potential materials which are likely to be evolved in the era of Industry 4.0 and to identify their potential uses.

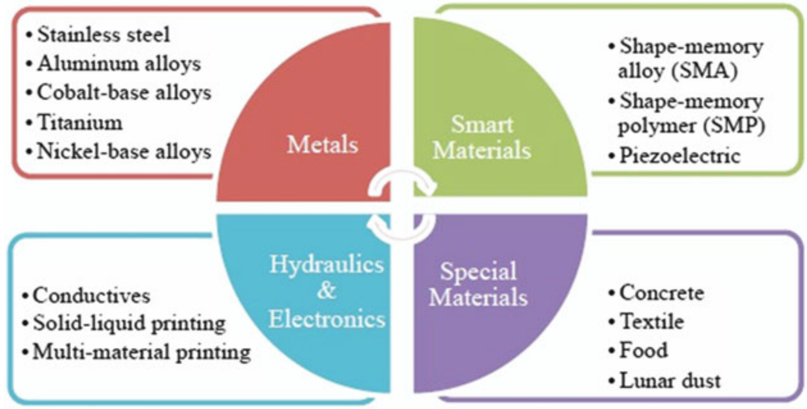


Fig. 3 Materials used in additive manufacturing [3]

Design flexibility, mass customization, minimization of waste and the capacity to produce complicated constructions are the primary advantages of additive manufacturing. The present situation of growth of 3DP products involves, among many others, concrete [31], the use of wood, metal alloys, metal composites, polymer composites, and ceramic composites. The 3DP technology includes a broad variety of products used in a wide range of sectors (including jewelry, aerospace, dentistry, automotive, petroleum and gas, orthopedic printed electronics, and [32] tooling). Figure 3 presents an outline of the most frequently used products in AM.

The elements deemed to fuel the additive price of manufacturing are metal costs, labor costs, machine costs, and cost of energy consumption. Material expenses for methods of laser sintering are a significant percentage of the expenses of additive production. The labor cost would be 2–3% and less than 1% of energy consumption [5].

2.1 Metal Additive Manufacturing

Because of the favorable mechanical characteristics of metals, they are probably the most usual substances in engineering. As an effect, the 3D printing trade is looking for fresh options for producing metallic parts that can replace their traditionally manufactured equivalents. Fresh enlargements in 3D printing technology boosts the efforts in the vital study industry: Metal Additive Manufacturing (MAM). AM techniques have freshly made it possible to produce many metallic components using stainless steel, aluminum, titanium, etc. as the key element of the method [30]. Most company electronic 3D printers use metal powders, while other appropriate fabric compositions [26] have also been investigated for MAM.

In addition, the microstructure arising from AM affects the mechanical characteristics of the components, such as tensile/fatigue behavior. Consequently, problems relating to microstructure, stage structure, and thermal therapy have lately drawn the attention of the AM study community [29]. For example, Lee et al. [30] explored certain mechanical characteristics of parts manufactured using a laser-based MAM method, showing the mechanism of cracking. On the other side, much remains to be developed as the manufactured components have not yet fulfilled the standards of the industry. Some problems that need to be addressed include favorable costs, pace of manufacturing, improved tensile/fatigue/hardness behavior, improved ground performance, and homogeneous microstructure [31]. MAM is likely to become a main player in Industry 4.0 development in the fresh age as soon as it overcomes these present obstacles through advances in both material engineering and MAM procedures.

Because of the advantages this method provides, Metal AM has started to receive attention in the areas of aviation, petroleum and gas, marine, automotive, production instruments and medical applications. Each portion generated by AM can be distinctive and manufactured in an overly less time, making it possible to customize mass. AM also lowers the demands for installation by incorporating the amount of parts needed for installation into a sole component. It lessens general weight, time of manufacturing, the amount of necessary production procedures, the demands for price and equipment, and optimizes the mechanical characteristics needed [32].

Recently, one of the highly investigated fields is the additive production of intelligent materials and structures. Smart materials are objects that can alter their form or characteristics under the impact of internal stimulation. As a reaction to internal stimulation implemented by incorporating intelligent products, the AM-made parts can alter their form or characteristics over moment (the fourth aspect). This leads to a latest concept called 4D-printing (4DP), which includes structural changes over period [33].

2.2 Smart Materials

Intelligent materials have been recognized as those resulting from externally exposed circumstances that alter their form or material characteristics. They were also categorized as 4D printing products due to their evolving characteristics over moment.

The implementation of smart materials to the AM sector offers advantageous characteristics such as reconfiguring the printed framework and achieving the required material characteristics in moment. Generally speaking, Shape Memory Alloys (SMA) and Shape Memory Polymers (SMP) are used as 4D printing material to generate functional components of soft robotic systems, self-developing designs and regulated continuous folding applications [5].

For their fundamental characteristics of super-elasticity and heat shape restoration, shape memory alloys are considered. In applications varying from biomedical embeds to micro-electromechanical systems, some SMAs such as nickel-titanium have been widely used. SMPs are too susceptible to internal stimuli such as light, moisture, and heat gradient as another branch of intelligent products. Because of SMP's biocompatibility, there is increasing interest in its medical engineering applications [34]. SMP materials are also used in the apparel sector and jewelry applications were digital light processing is required [31]. Piezoelectric fabrics are also considered to be another notable option for 3D printing. 3D nanofabrication of such products can be explored in conjunction with the power conservation and actuation purposes [33]. All these industries are likely to use AM in the era of Industry 4.0 with further changes in the performance of manufactured components.

One of the latest application domains for intelligent materials is soft robotics, where researchers have observed that the functional parts with electro-active polymers can be enabled externally to modify their rigidity in a supervised way [34]. Hong et al. [35], for instance, described the self-folding/unfolding function of 3D printed SMPs as effective origami and proved the restrict ability of effective multi-material hinges. One key application of active hinges [32] is the self-opening satellite parts caused by an inner stimulus. Likewise, Khoo et al. [36] explored multi-material printing made up of hydrophilic polymer where forced deformations produce 3D shape self-evolution when exhibited to water. The outcomes of such explorations will pave the road for research into self-assembled forms. As a prospective result, smart products can be attainable for acute scenarios such as deep sea or space tour by triggering them by water or UV light, respectively.

To outline, 3D printing technique can speed up intelligent materials implementation. Potential applications would be structures of self-assembly, compact settings, stimulus-activated systems in severe settings, and programmable components that will be easily used in the coming age. However, further study on intelligent components requires to be carried out on fresh combinations of components, creative production procedures and changes in layout.

2.3 Printable Hydraulics and Electronics

Hong et al. [35] explored an experiment in multi-material AM, where the research presents printable hydraulics that concurrently produced strong and fluid products. Modeling of fused deposition, called Fused Deposition Modelling (FDM) with various nozzles was used to manufacture strong structures composed of stiff, versatile components and simultaneously fill the liquid. As a result, hydraulically actuated operating systems such as smooth robotic grippers were produced for installation in just one phase without further measures. Thus, 3D printing can provide an easy way to manufacture immediate robotics and ready-to-use functional devices.

The implementation of conductive drugs for AM in this fresh age allows for the incorporation of digital circuitry into the printed item. As a result, complete circuit integration into the associated item (so-called integrated electronics) becomes a significant subject. Pham et al. [37]'s research focused on one instance of smart digital integrated apps where LEDs and digital PCBs are integrated in an electronic gaming dice (3D printed). In another job, Cooper [38] researched 3D printing (for recovery reasons) of tailored items housing digital equipment. In a modern research on 3D printed operational parts, further examples of printed equipment such as quad-copters, stretchable tactile detectors and micro batteries are stated [39]. Such work findings show the potential of AM to manufacture intelligent items for flexible areas.

In summary, together with its electronics, AM offers possibilities to manufacture goods. In the Industry 4.0 age, the loading effectiveness of electronic devices may be improved, allowing more creative models to be produced with multi-material printing technique in just one phase.

2.4 Space Materials and Applications

In the previous sub-sections, an overall perspective on new AM products has been summarized. In this section, extra AM components are to be addressed shortly, which are probable to be used in the upcoming age. The latest debate on additive building focuses on building potential houses and infrastructure.

As a result, in civil engineering implementations, inquiries into concrete and other particular materials shape the foundation for printing technology [40]. As a distinct part, the fabric production innovations have increased the AM procedures in the apparel and jewelry sector. In the fashion sector, some of the benefits of AM include a fast development method (i.e. brief manufacturing time) and decreased packaging and transport costs [41]. Another exceptional material for 3D

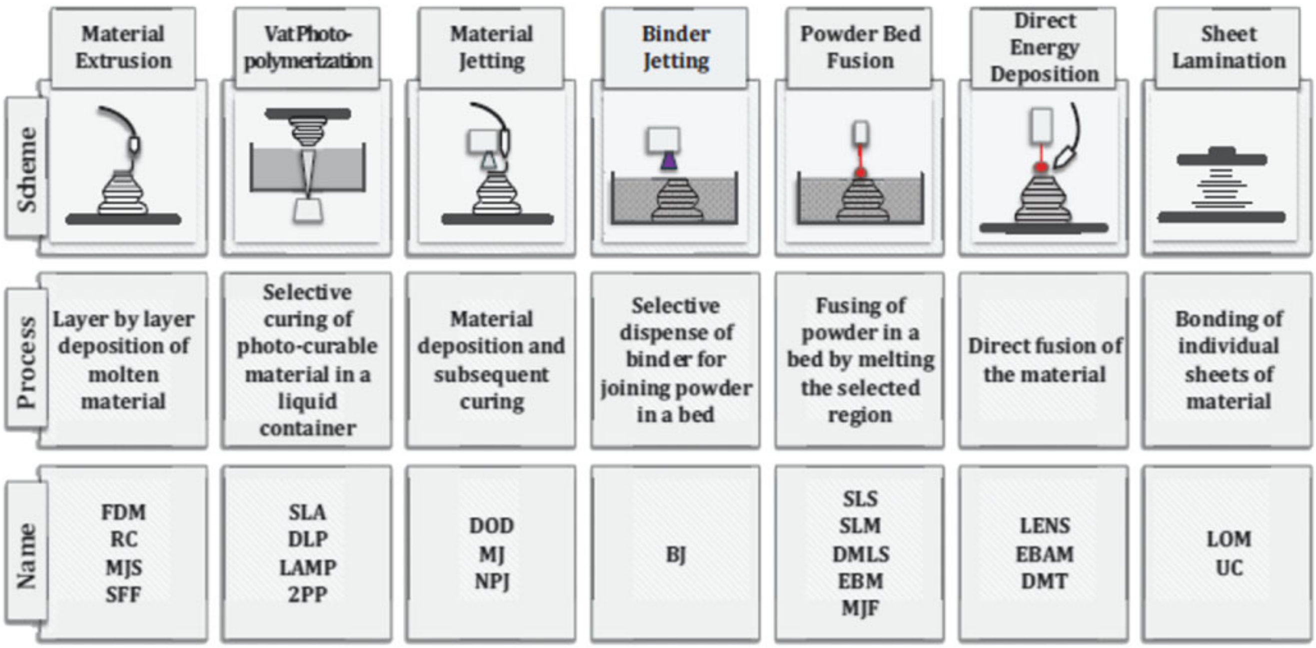


Fig. 4 Commonly used procedures in additive manufacturing [5]

printing is the food industry's consumable components. Using the extrusion-based AM methods, diverse applications with required ground texture and multiple nutritional content have recently been studied. While the process efficiency, permanence, and serviceability difficulties of the consumable products have not yet been achieved; AM may have a future in meat manufacturing [42]. Today, the use of this technique in space exploration is an uncommon subject. That is, some surveys researching Moondust's 3D printing to construct space colonies [43] discuss the practability of building habitations and infrastructure on the Moon with AM technology advances [44]. In addition, making excellent use of Mars' insitu assets as 3D printing material has been suggested for potential investigation projects to decrease the Earth's carried resources [45].

To sum up, some unique products and related procedures are shortly indicated with their consequences for the building sector, food, clothing, and even aviation sector. AM offers excellent opportunities to be investigated in the upcoming age, boosting competitiveness across a broad range of sectors.

3 3DP Processes

Three-dimensional printing has recently been outlined as it demonstrates a huge commitment to execute nearly all structural components of Computer-Aided Drafting (CAD). Various distinct methods are accessible for 3D printing, including, among others, Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Stereo Lithography (SL), Photopolymerization (PPT) [37]. Figure 4 demonstrates the procedures most frequently used in AM.

Novel AM procedures with a significant focus on those linked to MAM and hybrid production are described in this section. Although there is a substantial increase in the amount of creative AM procedures, they belong to the firmly-established basic techniques depicted in Fig. 4. With the technical advances in AM, more improved procedures are likely to be created. Most of these procedures, however, are created to print custom products such as metals that are usually used for non-industrial purposes.

Specific AM procedures have lately faced the need for substantial engineering applications in the framework of Industry 4.0. Since metals are the most popular product in the sector, significant thought has been given to the problem of MAM in this new era [31]. In fact, the future of production is anticipated to lead the sector to combine the use of these procedures. This fresh common sector, recognized as hybrid production, provides a manner to exercise subtractive techniques accompanying additives in order to manufacture stronger goods with higher ground performance, fatigue resistance, etc. [46]. Today, the increasing interest in hybrid production contributes to different combinations of production procedures beyond standard AM procedures.

3.1 Processes for Metal Manufacturing

Because of the comprehensive use of metallic components in almost every engineering field, MAM plays a crucial position for Industry 4.0. MAM procedures therefore dominate other kinds of techniques of printing. Four basic methods can be used to achieve AM of materials: (1) powder bed fusion, (2) direct power deposition, (3) fabric jetting, (4) binder jetting. The first two kinds are the industry's most prevalent ones. Powder-based techniques such as Selective Laser Sintering/Melting (SLS/SLM) and Electron Beam Freezing (EBM) use a power source to warm the content in a bath, named after the source used [47].

On the other side, during the processing of mixed metal, immediate power processing methods such as laser engineering net form (LENS) use heat power for boiling. Furthermore, there were also indirect MAM techniques accessible in which the molding for steel components and casting is immediately achieved [36]. Wire and arc additive production (WAAM) is a new metal AM method that is defined in conjunction with wire feeding as an integral arc welding process [48]. Due to its supremacy in manufacturing very big parts and its ability to shape all weldable materials, recent WAAM apps have been introduced in the aviation sector.

Nano Particle Jetting (NPJ) is a recently patented MAM process in which heated metal nanoparticles are thrown into a special liquid medium to construct extremely thin layers of the produced component [49]. Innovators of this fresh method argue that NPJ allows the finest surface finish among the existing MAM techniques to deliver elevated precision without deteriorating production velocity. In addition, NPJ is to deliver virtually the same metallurgical characteristics of strong counterparts and provide better production circumstances through the elimination of dangerous dust. Another innovative method proposed by Markforged [50] is Atomic Diffusion Additive Manufacturing (ADAM), where thick steel sections are printed layer by layer using the steel dust attached to a metal binder.

Progressive removal of the metal binder and sintering produces the finished item, resulting in outstanding mechanical features owing to the simultaneous sintering of the whole portion. Similarly, a new MAM technique called Single Pass Jetting (SPJ) has lately been announced by Desktop Metal Company [51]. A continuous binder jetting activity in the SPJ method causes steel oxide formation and compaction. The printing head's bi-directional motion makes the method 100 times quicker than standard laser-based metal additive techniques. The firm claims that SPJ provides the first 3D printer with its competitive manufacturing price per part estate that is competent of mass production.

Despite innovations in MAM, comprehensive study is still ongoing to solve challenges such as absence of system stability/repeatability along with restricted component size, elevated unit price, and bad completed product mechanical characteristics. Researchers have lately scrutinized optimization of parameters, searching for accurate sintering activities, and appropriate powder compounds, etc. [52] to identify remedies for these issues. Furthermore, study fields such as in-process surveillance and inspection have become very important in removing the obstacle for potential metal production [53]. Because MAM is inevitable for Industry 4.0's intelligent plants, the evolution of new procedures and associated techniques is likely to accelerate in the foreseeable future.

The fundamental concept of the SL method is photopolymerization, which is the method of converting a fluid monomer or tissue into a solidified tissue by adding ultraviolet light that functions as a catalyst for the responses; this method is also known as ultraviolet curing. Like pottery, powders can also be placed in the liquid [39].

Prometal is a 3DP method for the construction and death of injection instruments. This is a method based on powder that uses stainless steel. The method of printing takes place when a fluid binder is spurted into metal dust in jets [37]. SLS is already a 3DP process where a carbon dioxide laser beam [41] is used to sinter or fuse a powder.

FDM is a 3DP method where a slender metal filament carries a device where it is melted by a print head and is typically 0.25 mm thick. Materials used in this method include polyphenylsulfone (PPSF), polycarbonate (PC), PC-ABS blends, Acrylonitrile Butadiene Styrene (ABS), and medical-grade PC-ISO. The primary benefits of this method are that there is no requirement for chemical post-procedures, no cure resins, less costly machines and equipment that result in a more cost-effective procedure [45]. The drawbacks are that the resolution on the z axis is small relative to other additive production processes (0.25 mm), so if a clean surface is required a finishing method is needed and it is a slow method that sometimes takes days to construct big complicated components [44]. Few designs allow two methods to save time; a completely thick mode and a small mode that saves time but clearly reduces the mechanical characteristics [43].

Electron Beam Melting (EBM) is a method that uses an elevated voltage electron laser beam, typically 30–60 KV, to melt the dust. The method requires place in a large void room to prevent problems with oxidation as it is designed for the construction of steel components. The method is very comparable to SLS other than this. EBM can also process a wide range of pre-alloyed materials. One of the potential applications of this method is exterior space production as everything is accomplished in a large vacuum room [54].

Polyjet is an AM method that produces physical designs using inkjet techniques. The inkjet head rotates in the x and y axes depositing a photopolymer that is healed after each layer is finished by ultraviolet lamps. The density of the coating obtained in this method is 16 μm, resulting in elevated transparency of the manufactured components. The components that this method produces, however, are softer than others, such as stereolithography and selective laser sintering. A gel-type plastic is used to support the characteristics of the overhang and this material is thrown water after the method is completed. Multiple color components can be constructed with this method [46].

It is worth noting that multi-material extrusion in 3DP is receiving recognition owing to a broad range of opportunities provided, motivated in particular by the mercantile accessibility of a broad range of untraditional filament components. As a consequence, it is feasible to print designs that are not restricted to artistic reasons, but can now also give higher features and hence adapted for its function with mechanical efficiency [47].

It is shown that the use of AM methods is beneficial for components that have a large purchase: fly percentage, have a complicated structure, have a large price of solid-based raw material used for machining, have poor machining speeds and are hard and costly to process. For a conventional aerospace-Titanium alloy over a spectrum of purchases, the particular price of material unloaded by additive production technologies needed to provide a 30% saving over standard machines from strong methods is projected: fly ratios [50].

3.2 Hybrid Manufacturing Processes

Hybrid procedures describe the mixture of additive-and subtractive manufacturing (SM) procedures that are implemented sequentially or incorporated in mode, including adequate fastening and components orientation control [50]. This method is used for both enhancing dimensional precision and speeding up the manufacturing method as a whole. In addition, hybrid methods can be used to solve the issue of producing complex fields where a single production method (subtractive or additive) is not sufficient [53].

In the last century, scientists have developed hybrid approaches to create goods with chosen engineering attributes [55]. Hagel [56] have recently created a hybrid fast prototyping scheme in which FDM was used as an additive method in which the extruder was intended to move from AM to SM without compromising workspace. In a comparable research, CNC machining in regards to the deposition angle of the FDM is accompanied by the FDM method in order to obtain reduced ground roughness of the item and not reduce its surface morphology [57]. On the other side, for metals, a hybrid method composed of EBM and quick CNC machining has suggested improving system efficiency [58]. In their research, together with adequate process scheduling, milling is used as SM technique. Similarly, in order to achieve required surface finish, Rayna et al. [59] implemented a mixture of selective laser melting with accuracy milling. Hybrid deposition and later micro-rolling (recognized as HDMR) have also been used to manufacture components of steel planes with exceptional mechanical properties [60].

The problem of further enhancing hybrid manufacturing efficiency is strongly linked to sophisticated process scheduling, layout and production integration. A structure suggested by Chen et al. [60] implements the mix of AM/SM and test procedures. In this context, an algorithm is designed to arrange manufacturing operations/sequences with appropriate parameters while optimizing manufacturing time and resource utilization [61]. Related ideas are introduced in a notable implementation in which the hybrid method was used by incorporating material and consecutive machining to reuse current products [62]. Following the Fourth Industrial Revolution, future advancement on hybrid systems may come from IT innovations and the effective use of accessible data. As a result of both fresh hybrid procedures and efficient system scheduling, manufacturing demands are probable to be fulfilled with the enhanced performance of the item.

4 Additive Manufacturing in Industry 4.0

Industry 4.0 provides cybernetic and physical devices, as shown in Fig. 1, to collaborate profitably with the objective of constructing smart plants, redefining the function of humans. There are many meanings to the word Industry 4.0. It aims to define the smart plant, with the Internet of Things interconnecting all procedures. In this sector, the first developments engaged the inclusion of higher flexibility and production process individualization [50].

Industry 4.0's paradigm is fundamentally described in three aspects: (1) horizontal inclusion throughout the whole value development network, (2) end-to-end engineering throughout the entire consumer life cycle, and (3) vertical integration and networked production systems [58]. Industry 4.0 encourages the inclusion of smart manufacturing systems and sophisticated IT. In this, production is regarded as an important ingredient [39].

In Industry 4.0, the application of 3DP technology will be crucial for system effectiveness and decreased complexity, premising for fast prototyping and extremely decentralized manufacturing procedures: the product model could simply be off to the nearest 'printing' place for the customer, removing the need of intermediate manufacturing, storage and warehousing measures [52]. Table 1 shows an overview of the significant innovations and anticipated development in Industry 4.0 for the different factors of value development:

Table 1 Major developments and growth in Industry 4.0

Equipment	Highly automated machine equipment and robots will be used to characterize the production machinery. The machinery will be prepared to adjust flexibly to modifications in the other variables of value development, e.g. the robots can collaborate on joint assignments with the workers [58]
Human	Current production workers face an elevated danger of being largely automated. Thus, the number of employees will reduce. More information on this research will include the remaining production employment as well as more short-term and hard-to-plan tasks [63]. Workers are progressively required to track automated machinery, are incorporated into decentralized decision-making, and are engineering operations as part of end-to-end engineering [53]
Organization	From a certain point onwards, a central instance cannot manage the growing organizational complexity of the production scheme. Consequently, decision-making will be moved from a key example to decentralized cases. The decentralized cases will regard local decision-making data autonomously. The choice itself will be made by employees or machinery using artificial intelligence methods [53]
Process	Additive production techniques, also recognized as 3D printing, can be progressively implemented in value creation procedures, as additive production expenses have fallen quickly over the past few years by concurrently expanding in terms of velocity and accuracy. This enables more complicated, heavier and lighter geometries to be designed as well as the implementation of additive production to greater amounts and bigger product scales [64]
Product	The goods will be produced in batch size which is in accordance with the customer's person requirements [51]. This mass item customization integrates the client into the value chain as soon as feasible. As a part of fresh company designs, the physical item will also be mixed with fresh facilities providing features and access to the client rather than brand ownership [63]

5 Industrialization of 3DP Technology

Industrial businesses are now facing increasingly complicated difficulties in the creation of products. Customers are asking for creative, separately customized goods at a fair cost with elevated consumer quality. Furthermore, the financial lifetime of goods reduces, forcing businesses to shorten their business time and their growth cycles [64]. Competition in fertile economies is increasing through globalization. Foreign business imitators create it more difficult for businesses to retain market stocks that have been achieved [60]. A fresh manufacturing technique, the AM [46], provides one alternative to boost creativity and shorten time to market.

AM innovation is gradually becoming the key technology at present [64] and there is increasing agreement that 3DP systems will be a fresh significant technological revolution [60]. Figure 5 demonstrates potential Industry 4.0's 3DP operation:

Some 3DP technology implementations in different manufacturing sections are mentioned below:

5.1 Pharmaceutical Sector

In the 4.0 pharmaceutical sector, 3DP is anticipated to be an extremely innovative technique. The primary benefits of 3DP in specific are the manufacturing of limited drug batches, each with custom dosages, forms, dimensions and discharge features. Producing individualized medicines thus becomes a fact. In the short duration, 3DP could be expanded over the drug manufacturing stage from pre-clinical implementations and clinical testing to first-line medical care [59]. Exploring the changing technologies of the pharmaceutical industry 4.0 supports sustainable value creation, leads to a more efficient, better and customized pharmaceutical industry and, in the long go, provides competitive benefits for pharmaceutical businesses. To merge potential activities and pharmaceutical governance throughout the entire life cycle, a more viable pharmaceutical supply chain should be developed [61].

5.2 Biomedicine

Human bodies' 3DP is one of the world's recent developments in today's medical sector. Using present bio-printing technique, human bodies can be printed straight from neurons. In today's globe, many science and education institutions have invested millions of funds to remove the boundaries of body imprinting. The researchers' objective is to effectively substitute a human body. Various devices and equipment are sought around the globe during the method of organ production. With this technique, the most printed bodies are brain, cartilage, hair, heart and bone cells, etc. The reproduction of living bodies (print organ life), processing settings and post-processing (such as autoclaving) are some of the main difficulties in these techniques. Advances in this field obviously indicate that scientists are very near to the future, where it is possible to replace the human body with the printed organ [32]. 3D printing has shown feasibility in various medical applications, inclusive of the production of eyeglasses, custom prosthetic devices and dental embeds [62]. 3DP is also common with the capacity to print porous scaffolds with manufactured shape, restricted chemistry, and interconnected porosity. Some of these inorganic biodegradable scaffolds have been shown to be ideal for bone tissue technology [65]. 3D printing is a powerful tissue engineering tool that enables 3D cell growth within complex 3D biomimetic architectures [66].

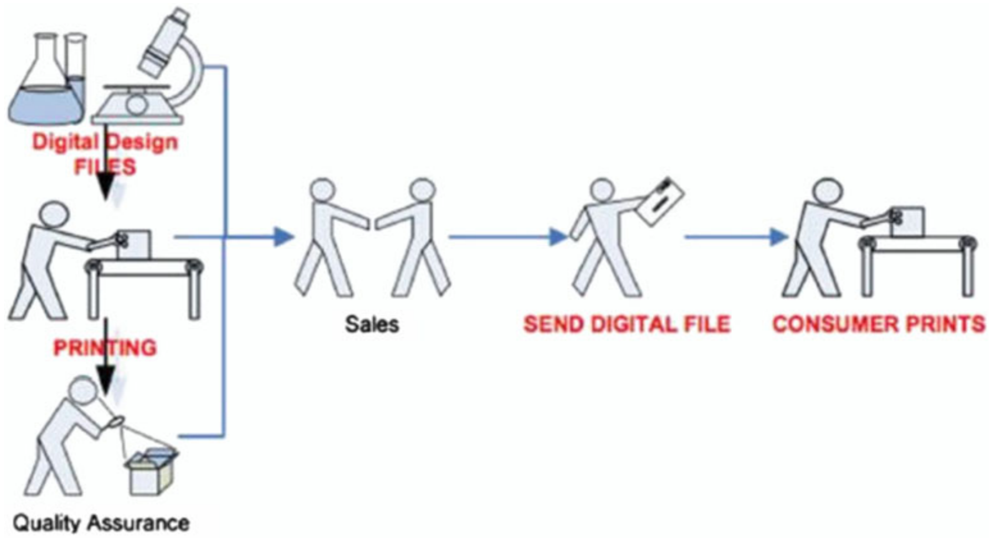


Fig. 5 Future 3DP procedure [1]

5.3 Food Industry

Because of its many benefits like tailored food models, individualized nutrition, streamlined supply chain and extending accessible food content, 3DP food has been extensively researched in the food sector in latest years. However, three primary elements should be regarded in order to achieve a precise idea: material characteristics, system parameters and techniques of post-processing, with unique regard to rheological characteristics, attachment processes, thermodynamic characteristics, techniques of pre-treatment and production powders. Furthermore, there are three primary difficulties in food 3DP: (1) printing precision and precision (2) process efficiency and (3) manufacturing of multicolored, multiflavored goods [67].

5.4 Fashion Industry

3DP has a large number of benefits over conventional production procedures, including a forwarded construction method, reduced production time, and reduced stock, warehousing, shipping, and shipping expenses. This paper describes the five kinds of 3DP techniques with high opportunities for fashion implementation, including stereolithography, selective laser sintering, mixed deposition modeling, PolyJet, and binder jetting [68].

5.5 Electrical Parts

3D printing is a distinctive technology that can provide a large degree of liberty to customize practical goods that integrate electrical elements such as detectors in wearable apps. In the manufacture of such devices and detectors, the accessibility of cheap, secure, electrically conductive material will be crucial before the complete potential of 3D printing can be realized for tailored goods integrating electrical components. To date, there is still a lack of 3D printable conductive filaments with adequately elevated conductivity to produce practical devices for mixed deposition modeling [69].

5.6 Casting Industry

Applying 3DP foundry moulds technology allows for a significant speed of work at prototype castings, allowing for a decrease in the cost of foundry-mold production. A shell mould can be produced and then complemented with cheaper molding material to decrease production expenses. The foundry mould making technique in three-dimensional printing method provides enormous capacity for production. For this reason; further study on its implementation for multiple non-ferrous alloy cast components is recommended [70, 71].

There is an increasing agreement, therefore, that 3D printing techniques are playing a significant part in the industrial technological revolution. History has shown that technological revolution is a pitfall for many companies without appropriate company model development. In the era of 3DP, the issue is then complied by the reality that the implementation of these techniques took place in four consecutive stages (fast prototyping, fast tooling, electronic manufacturing and house manufacturing) corresponding to a distinct stage of 3DP participation in the production process [61].

5.7 Design Related Issues

Engineers and developers have little experience and inadequate understanding about AM's capacities and constraints as a comparatively fresh production technique. Industry 4.0's evolving digitalization has developed possibilities for overcoming design-related obstacles to new manufacturing techniques. The advances on the latest computer instruments for simulation, visualization and immediate assessment are immediately linked to contemporary manufacturing. The design associated problems are to be shortly discussed in this section.

Industry 4.0's cyber technology advances provide developers with improved computing assets, which then contribute to increased productivity and effectiveness in AM. Design for Additive Manufacturing (DfAM) has lately been implemented as one of the additional design instruments to optimally select system parameters (such as price, time, performance, accuracy and CAD limitations).

In reality, DfAM is split into two sections that focus on solutions to a particular layout structure and techniques for improving particular product functionality [65]. The former offers a wide view for inexperienced developers to choose the finest alternatives in AM's design and production phases. For example, Salonitis suggested a particular DfAM technique for designing fresh goods (or reforming an current one) in which client wants, functional specifications, layout parameters and system factors are assessed simultaneously [66]. In a comparable research, another DfAM structure, in which production and installation problems are regarded in the early phase of item growth, offers developers with appropriate choices of materials and processes [67]. On the other side, the later method (i.e. DfAM's second category) provides superior goods for a specific purpose at the cost of giving less attention to other variables in effect [68]. The goal-specific approach is primarily focused on topology optimization (TO) as part of the second branch. It is described as a technique to obtain the finest geometry/shape feasible while meeting certain demands. For instance, product quantity optimization while minimal compliance with components has been studied frequently [72]. There are several novel TO apps for reduced weight-to-stiffness ratio [33]. The use of TO in ideal thermal transfer of buildings manufactured through AM [69] is an exciting objective-specific design implementation. Similarly, in comparison to hybrid AM [70], the techniques such as Solid Isotropic Material with Penalization have lately been explored. In such techniques, IoT and Big data plays an important role [73–78].

Other layout optimization research focused on parameters such as slice density, CAD model geometric data, part construction orientation, and support structures [79, 80]. CAD software problems have drawn a good deal of concern from scientists in latest years among the parameters mentioned. For example, in favor of new electronic file kinds recognized as AM File Format (AMF) and 3D Fabrication Format (3MF) [56], drawbacks originating from STL file format have been studied. Similarly, Junk and Kuen studied the use of open-source CAD technology projects [65]. Several cutting algorithms and effective system scheduling methods were also suggested, such as the one that capitalizes on inhomogeneous interior coherence to minimize printer head movements [66].

As the industrial and academic study group gains knowledge through effective implementation of new computing techniques and new design methodologies, the significance of design-related problems will be significantly increased. Consequently, in the near future, AM's limitations and capacities can be handled more efficiently.

6 Drawbacks and Future Directions

Industry 4.0 has drawn the attention of both academics and sector over the past century as it is regarded as the significant paradigm change in potential manufacturing. AM, as a main innovation in the framework of the upcoming revolution, provides excellent possibilities for future innovations in this fresh age, provided that in the near future some present obstacles are overcome. In this section, along with supplementary suggestions, some predictable projections about AM and its probable disadvantages are to be mentioned.

Because of the significant drawbacks to its velocity, precision, repeatability, and price of manufacturing, AM may not be chosen in standard industrial facilities, particularly for mass production of periodic components. However, in the manufacture of complex and tailored items, it still has superiorities over standard production techniques. In reality, AM offers a wide variety of production opportunities in terms of content (polymers to metals), size (nanoscale to big components), and functionality (self-assembly for optimum thermal transfer) [67]. The resistance of the produced components is another AM deficiency that can be fostered by new materials/processes that cause improved microstructures and development of the correct design/topology. In addition, hybrid production makes it possible to compensate for certain disadvantages, such as the ground performance of the product, as well as offering possibilities for repairing/repairing current components.

Decentralization can become feasible as a potential anticipation by spreading the workload across factories/machines through the efficient use of cloud services [79]. Another direction for AM in the future is the problem of sustainability, where AM can perform an important part in decreasing waste capital and decreasing power usage by using just-in-time manufacturing [80]. In addition, it is expected that 3D printing and electronic production will affect society. First, it is necessary to redefine the position of employees in the sector in such a way that they undertake management/design/analysis employment rather than being employees. Second, platforms such as do-it-ourself and motion of manufacturers promote the involvement of customers in the planning and production stage [68]. For example, by converting the school into a tiny hands-on workshop with an affordable 3D printer, learners can design their own goods.

In the Industry 4.0 age, there are several common areas of research on additive production: fresh material compounds for enhanced microstructures, creative design frameworks for appropriate parameter estimates, enhanced CAD services for optimization/simulation/modeling reasons, fresh AM/hybrid procedures along with real-time system monitoring and inspection, etc. The primary suggestion is the study community, sector, and governments working together to resolve all these present obstacles on AM. In addition, AM's being comparatively fresh innovation involves issues in the sector of standardization, needing some job on suitable certification [72].

7 Conclusion

Cyber-physical inclusion promotes high-efficiency intelligent factories that are able to manufacture tailored goods of high quality. On the one hand, IT progress has accelerated the shift to the upcoming manufacturing age. Indeed, the presence of the Fourth Industrial Revolution relies heavily on AM's capacities. These problems have been summarized in this article in three particular subjects, namely problems of materials, procedures and layout.

More interdisciplinary study attempts are probable to be spent in the future. On the other side, there will be a remarkable redefinition of the position of developers, warehouses and clients as the production company will be spread to many distinct places such as tiny workplaces or households. In other words, with personal-and tailored manufacturing, the present obstacle of mass manufacturing on site will be overcome.

No doubt 3DP techniques will lead to the next significant manufacturing revolution. The Additive Manufacturing performs a major significant role in Industry 4.0 due to its versatility, reduction in time and expenses, being crucial for system effectiveness and decreasing its complications, enabling fast prototyping and extremely decentralized manufacturing procedures. AM is currently taking benefit of more and more manufacturing sections. Future intelligent companies have all their procedures interconnected through the Internet of Things, integrating higher flexibility and production procedures individualization.

As a particular perspective, there is a tendency towards the availability of fresh products for AM such as intelligent metals and metallic constituents in order to attain the necessary features. Another common tendency is to create functional parts/machines in just one manufacturing phase. Due to the possibilities offered by the new AM techniques, only the imaginations of the people limit the design-and manufacturing difficulties.

References

1. M. Mavri, Redesigning a Production Chain Based on 3D Printing Technology. Knowledge and Process Management, 22(3):141-147, 2015.
2. J. Zhou, Digitalization and intelligentization of manufacturing industry. Advances in Manufacturing, 1(1):1-7, 2013.
3. S. Vaidya, P. Ambad, S. Bochle, Industry 4.0 – A Glimpse. Procedia Manufacturing, 20:233–238, 2018.
4. A. Thompson et al. Design for Additive Manufacturing: Trends, Opportunities, Considerations and Constraints. CIRP Annals – Manufacturing Technology, 65(2):737-760, 2016.
5. U.M. Dilberoglu, B. Gharehpapagh, U. Yaman, M. Dolen, The role of additive manufacturing in the era of Industry 4.0. Procedia Manufacturing, 11:545-554, 2017.
6. Rameshwar, R., Solanki, A., Nayyar, A., & Mahapatra, B. (2020). Green and Smart Buildings: A Key to Sustainable Global Solutions. In Green Building Management and Smart Automation (pp. 146-163). IGI Global.
7. Singh, S. P., Nayyar, A., Kaur, H., & Singla, A. (2019). Dynamic Task Scheduling using Balanced VM Allocation Policy for Fog Computing Platforms. Scalable Computing: Practice and Experience, 20(2), 433-456.
8. Kaur, A., Gupta, P., Singh, M., & Nayyar, A. (2019). Data Placement in Era of Cloud Computing: a Survey, Taxonomy and Open Research Issues. Scalable Computing: Practice and Experience, 20 (2), 377-398.
9. Singh, P., Gupta, P., Jyoti, K., & Nayyar, A. (2019). Research on Auto-Scaling of Web Applications in Cloud: Survey, Trends and Future Directions. Scalable Computing: Practice and Experience, 20 (2), 399-432.
10. Singh, S. P., Nayyar, A., Kumar, R., & Sharma, A. (2019). Fog computing: from architecture to edge computing and big data processing. The Journal of Supercomputing, 75(4), 2070-2105.
11. Pramanik, P. K. D., Pareek, G., & Nayyar, A. (2019). Security and Privacy in Remote Healthcare: Issues, Solutions, and Standards. In Telemedicine Technologies (pp. 201-225). Academic Press.
12. Pramanik, P. K. D., Nayyar, A., & Pareek, G. (2019). WBAN: Driving e-healthcare Beyond Telemedicine to Remote Health Monitoring: Architecture and Protocols. In Telemedicine Technologies (pp. 89-119). Academic Press.
13. Das, S., & Nayyar, A. (2019). Innovative Ideas to Manage Urban Traffic Congestion in Cognitive Cities. In Driving the Development, Management, and Sustainability of Cognitive Cities (pp. 139-162). IGI Global.
14. Nayyar, A., Jain, R., Mahapatra, B., & Singh, A. (2019). Cyber Security Challenges for Smart Cities. In Driving the Development, Management, and Sustainability of Cognitive Cities (pp. 27-54). IGI Global.
15. Nayyar, A., Puri, V., & Nguyen, N. G. (2019). BioSenHealth 1.0: A Novel Internet of Medical Things (IoMT)-Based Patient Health

Monitoring System. In International Conference on Innovative Computing and Communications (pp. 155-164). Springer, Singapore.
16. Nayyar, A., & Nguyen, G. N. (2018). Augmenting Dental Care: A Current Perspective. Emerging Technologies for Health and Medicine: Virtual Reality, Augmented Reality, Artificial Intelligence, Internet of Things, Robotics, Industry 4.0, 51-67.
17. Batth, R. S., Nayyar, A., & Nagpal, A. (2018, August). Internet of Robotic Things: Driving Intelligent Robotics of Future-Concept, Architecture, Applications and Technologies. In 2018 4th International Conference on Computing Sciences (ICCS) (pp. 151-160). IEEE.
18. Nayyar, A., Ba, C. H., Duc, N. P. C., & Binh, H. D. (2018, August). Smart-IoUT 1.0: A Smart Aquatic Monitoring Network Based on Internet of Underwater Things (IoUT). In International Conference on Industrial Networks and Intelligent Systems (pp. 191-207). Springer, Cham.
19. Nayyar, A., Mahapatra, B., Le, D., & Suseendran, G. (2018). Virtual Reality (VR) & Augmented Reality (AR) technologies for tourism and hospitality industry. International Journal of Engineering & Technology, 7(2.21), 156-160.
20. Puri, V., Nayyar, A., & Raja, L. (2017). Agriculture drones: A modern breakthrough in precision agriculture. Journal of Statistics and Management Systems, 20(4), 507-518.
21. Nayyar, A., & Puri, V. (2017). Comprehensive Analysis & Performance Comparison of Clustering Algorithms for Big Data. Review of Computer Engineering Research, 4(2), 54-80.
22. Anand Nayyar, E. (2016, November). Vikram Puri, "In Smart Farming: IoT Based Smart Sensors Agriculture Stick for Live Temprature and Moisture Monitoring using Arduino, Cloud Computing & Solar Technology" [Online], Conference: The International Conference on Communication and Computing Systems (ICCCS-2016), Novemer.
23. Nayyar, A. (2011). INTEROPERABILITY OF CLOUD COMPUTING WITH WEB SERVICES. International Journal of ElectroComputational World & Knowledge Interface, 1(1).
24. Nayyar, A. (2011). Private Virtual Infrastructure (PVI) Model for Cloud Computing. International Journal of Software Engineering Research and Practices, 1(1), 10-14.
25. Nayyar, A., & Puri, V. (2016). Data glove: Internet of things (iot) based smart wearable gadget. British Journal of Mathematics & Computer Science, 15(5).
26. C. Lindemann, U. Jahnke, M. Moi, R. Koch, Analyzing Product Lifecycle Costs for a Better Understanding of Cost Drivers in Additive Manufacturing, Conference: Solid Freeform Fabrication Symposium - An Additive Manufacturing Conference, At: Austin, TX, USA, Volume: 23th, 177-188, 2012.
27. L. Wang, & G. Wang, Big Data in Cyber-Physical Systems, Digital Manufacturing and Industry 4.0. International Journal of Engineering and Manufacturing, 4:1-8, 2016.
28. N. Hopkinson, R.J.M. Hague, P.M. Dickens, Rapid manufacturing. An industrial revolution for the digital age. Chichester, England: Ed. John Wiley, 304 p., 2006.
29. T., Birtchnell, & J. Urry, 3D, SF and the future. Futures, 5025–5034, 2013
30. J-Y., Lee, J., An, C.K. Chua, Fundamentals and applications of 3D printing for novel materials. Applied Materials Today, 7:120-133, 2017.
31. T. Duda, & L.V. Raghavan, 3D Metal Printing Technology. IFAC-PapersOnLine, 49-29:103–110, 2016.
32. T.D. Ngo, A. Kashani, G. Imbalzano, K.T.Q. Nguyen, D. Hui, Additive manufacturing (3D printing): A review of materials, methods, applications and challenges. Composites Part B: Engineering, 143(1):172-196, 2018.
33. V. Bhavar et al., A Review on Powder Bed Fusion Technology of Metal Additive Manufacturing, 4th International conference and exhibition on Additive Manufacturing Technologies-AM-2014, September 1,2, Bangalore, India, 2014,
34. D. S. Thomas, & S.W. Gilbert, Costs and Cost Effectiveness of Additive Manufacturing – A Literature Review and Discussion, NIST Special Publication 1176, 89p., 2014.
35. S.Y. Hong, Y.C.; Kim, M.; Wang, H-I.; Kim, et al., Experimental investigation of mechanical properties of UV-Curable 3D printing materials. Polymer, 145:88-94, 2018.
36. Z.X. Khoo, J.E.M Teoh, Y. Liu, C.K. Chua, S. Yang, J. An, K.F. Leong, W.Y. Yeong, 3D printing of smart materials: A review on recent progresses in 4D printing. Virtual and Physical Prototyping, 10:3:103-122, 2015.
37. D.T. Pham and C. Ji, Design for stereolithography. Proceedings of the Institution of Mechanical Engineers, 214(5):635–640, 2000.
38. K. Cooper, Rapid Prototyping Technology, CRC Press, 248 p., 2001.
39. T. Hwa-Hsing, C. Ming-Lu, and Y. Hsiao-Chuan, Slurrybased selective laser sintering of polymer-coated ceramic powders to fabricate high strength alumina parts. Journal of the European Ceramic Society, 31(8):1383–1388, 2011.
40. G.V. Salmoria, R.A. Paggi, A. Lago, and V.E. Beal, Microstructural and mechanical characterization of PA12/ MWCNTs nanocomposite manufactured by selective laser sintering. Polymer Testing, 30(6):611–615, 2011.
41. R.I. Noorani, Rapid Prototyping — Principles and Applications, John Wiley & Sons, 400 p., 2006.
42. P.P. Kruth, Material incress manufacturing by rapid prototyping techniques. CIRP Annals — Manufacturing Technology, 40 (2):603–614, 1991.
43. K.V. Wong, & A. Hernandez, A Review of Additive Manufacturing. ISRN Mechanical Engineering, Article ID 208760:1-10, 2012.
44. S. Morvan, R. Hochsmann, M. Sakamoto, ProMetal RCT (TM) process for fabrication of complex sand molds and sand cores. Rapid Prototyping, 11(2):1–7, 2005.
45. L. Murr, S. Gaytan, D. Ramirez et al., Metal fabrication by additive manufacturing using laser and electron beam melting technologies. Journal of Materials Science & Technology, 28(1):1–14, 2012.
46. C. Semetay, Laser engineered net shaping (LENS) modeling using welding simulation concepts [ProQuest Dissertations and Theses], Lehigh University, 2007.
47. V. Petrovic, J. Vicente, H. Gonzalez et al., Additive layered manufacturing: sectors of industrial application shown through case studies. International Journal of Production Research, 49 (4):1061–1079, 2011.
48. S.C. Ligon, R. Liska, J. Stampfl, M. Gurr, R. Mülhaupt, Polymers for 3D Printing and Customized Additive Manufacturing. Chem. Rev., 9; 117(15):10212–10290, 2017.
49. J. Gonzalez-Gutierrez, S. Cano, S. Schuschnigg, C. Kukla, J. Sapkota, C. Holzer, Additive Manufacturing of Metallic and Ceramic Components by the Material Extrusion of Highly-Filled Polymers: A Review and Future Perspectives. Materials, 11(5):840, 2018.
50. J. Allen, An Investigation into the Comparative Costs of Additive Manufacture vs. Machine from Solid for Aero Engine Parts. In Cost Effective Manufacture via Net-Shape Processing (17-1). Meeting Proceedings RTO-MP-AVT-139, Paper 17. Neuilly-sur-Seine, France: RTO. Available from: https://apps.dtic.mil/dtic/tr/fulltext/u2/a521730.pdf
51. C.W.J. Lim, K.Q. Le, Q. Lu, C.H. Wong, An Overview of 3-D Printing in Manufacturing Aerospace and Automotive Industries. Potentials IEEE, 35(4):18-22, 2016.
52. A. Luque, M.E. Peralta, A. De Las Heras, A. Córdoba, State of the Industry 4.0 in the Andalusian food sector. Procedia Manufacturing. 13: 1199-1205, 2017.
53. T. Stock, & G. Seliger, Opportunities of Sustainable Manufacturing in Industry 4.0. Procedia CIRP, 40:536–541, 2016.

54. R. Singh, Process capability study of polyjet printing for plastic components. Journal of Mechanical Science and Technology, 25 (4):1011–1015, 2011.
55. G. Specht, C. Beckmann, J. Amelingmeyer, F&E-Management KompetenzimInnovationsmanagement; VerlagSchäffer-Poeschel; Stuttgart, 2002.
56. J. Hagel III et al., The future of manufacturing, Deloitte University Press, 24 p., 2015, Available: http://dupress.com/articles/future-of-manufacturing-industry/
57. D. Spath, O. Ganschar, S. Gerlach, M. Hämmerle, T. Krause, S. Schlund, Produktionsarbeit der Zukunft – Industrie 4.0. Fraunhofer IAO, Fraunhofer Verlag, 2013.
58. K. Santos, E. Loures, F. Piechnicki, O. Canciglieri, Opportunities Assessment of Product Development Process in Industry 4.0. Procedia Manufacturing, 11:1358–1365, 2017.
59. T. Rayna, & L. Striukova, From rapid prototyping to home fabrication: How 3D printing is changing business model innovation. Technological Forecasting and Social Change, 102:214-224, 2016.
60. L. Chen, Y. He, Y. Yang, S. Niu, H. Ren. The research status and development trend of additive manufacturing technology. The International Journal of Advanced Manufacturing Technology, 89 (9-12):3651-3660, 2017.
61. S.J. Trenfield, A. Award, A. Goyanes, S. Gaisford, A. W Basit, 3D Printing Pharmaceuticals: Drug Development to Frontline Care. Trends in Pharmacological Sciences. 39(5):440-451, 2018.
62. B. Ding, Pharma Industry 4.0: literature review and research opportunities in sustainable pharmaceutical supply chains. Process Safety and Environmental Protection. In press, 2018.
63. H. Kagermann, W. Lukas, W. Wahlster, Abschotten ist keine Alternative. In: VDI Nachrichten, Issue 16, 2015.
64. H.-J. Bullinger, Einführung in das Technologiemanagement; Modelle, Metho- den, Praxisbeispiele, TeubnerVerlag; Stuttgart, 1994.
65. C. Schubert, M.C. van Langeveld, L.A. Donoso, Innovations in 3D printing: a 3D overview from optics to organs. British Journal of Ophthalmology, 98(2):159-161, 2013.
66. S. Bose, S. Vahabzadeh, A. Bandyopadhyay, Bone tissue engineering using 3D printing. Materials Today, 16(12):496:504, 2013.
67. W. Zhu, X. Ma, M. Gou, D. Mei, K. Zhang, S. Chen, 3D printing of functional biomaterials for tissue engineering. Curr. Opin. Biotechnol., 2016 Aug;40:103-112, 2016.
68. C. Liu, C. Ho, J. Wang, The development of 3D food printer for printing fibrous meat materials. IOP Conf. Series: Materials Science and Engineering, 284(012019)1-9, 2017.
69. A. Vanderploeg, S-E Lee, M. Mamp The application of 3D printing technology in the fashion industry, International Journal of Fashion Design, Technology and Education, 10:2, 170-179, 2017.
70. S.W. Kwok et al., Electrically conductive filament for 3D-printed circuits and sensors. Applied Materials Today, 9:167-175, 2017.
71. G. Budzik, Possibilities of utilizing 3DP technology for foundry mould making. Archives of Foundry Engineering, 7(2):65-68., 2007.
72. I. Dankar, A. Haddarah, F.E.L. Omar, et al., 3D printing technology: The new era for food customization and elaboration. Trends in Food Science & Technology, 75: 231-242, 2018.
73. A. Kumari., S. Tanwar., S. Tyagi, N. Kumar, M. Maasberg, K. K. R. Choo "Multimedia Big Data Computing and Internet of Things Applications: A Taxonomy and Process Model", Journal of Network and Computer Applications, 124:169-195, 2018.
74. A. Kumari., S. Tanwar., S. Tyagi, N. Kumar, R. Parizi, K. K. R. Choo "Fog Data Analytics: A Taxonomy and Process Model", Journal of Network and Computer Applications, 128:90-104, 2019.
75. A. Kumari, S. Tanwar, S. Tyagi, N. Kumar, "Verification and Validation Techniques for Streaming Big Data Analytics in Internet of Things Environment", IET Networks, 2019, pp. 1-8, DOI: https://doi.org/10.1049/ietnet.2018.518, 2019.
76. J. Vora, S. Kanriya, S. Tanwar, S. Tyagi, N. Kumar, M. S. Obaidat, "TILAA: Tactile Internet-based Ambient Assistant Living In Fog Environment", Future Generation Computer Systems, Vol 98, pp. 635-649,, 2019.
77. Kumari A., Tanwar S., Tyagi S., Kumar N., "Fog Computing for Healthcare 4.0 Environment: Opportunities and Challenges", Computers & Electrical Engineering, Volume 72, pp. 1-13, 2018.
78. Vora J, Tanwar S, Tyagi S, Kumar N & Rodrigues J P C, "FAAL: Fog Computing-based Patient Monitoring System for Ambient Assisted Living", IEEE 19th International Conference on e-Health Networking, Applications and Services (Healthcom-2017), Dalian University, Dalian, China, 12-15 October 2017, pp. 1-6.
79. Horst, Diogo José, Charles Adriano Duvoisin, and Rogério de Almeida Vieira. "Additive Manufacturing at Industry 4.0: a Review." International Journal of Engineering and Technical Research 8, no. 8.
80. Dilberoglu, Ugur M., Bahar Gharehpapagh, Ulas Yaman, and Melik Dolen. "The role of additive manufacturing in the era of industry 4.0." Procedia Manufacturing 11: 545-554, 2017.

Pimal Khanpara is working as an Assistant Professor in the Computer Science and Engineering department, Institute of Technology, Nirma University since 2012. She pursued her BE (Information Technology) from Dharmsinh Desai University, Nadiad and MTech (Computer Science and Engineering) from Nirma University. She obtained her PhD degree from Gujarat Technological University in 2018 in the area of Survivable Mobile Ad hoc Networks. Her research interests are Wireless Network Communication, Network Security and Computer Architecture. She has been actively contributing to the domain of ad hoc networks through research papers and projects.

Dr. Sudeep Tanwar is an Associate Professor in Computer Science and Engineering Department at Institute of Technology, Nirma University, Ahmedabad, Gujarat, India. He is visiting Professor at Jan Wyzykowski University in Polkowice, Poland and University of Pitesti in Pitesti, Romania. He received B.Tech in 2002 from Kurukshetra University, India, M. Tech (Honor's) in 2009 from Guru Gobind Singh Indraprastha University, Delhi, India, and Ph. D. in 2016 from Mewar University, Chittorgarh, Rajasthan, India with specialization in Wireless Sensor Network. He has authored/coauthored more than 100 technical research papers in leading journals and conferences from IEEE, Elsevier, Springer, Wiley, etc. Some of his research findings are published in top-cited journals such as IEEE Transactions on TVT, IEEE Transactions on Industrial Informatics, Applied Soft Computing, Journal of Network and Computer Applications, Pervasive and Mobile Computing, International Journal of Communication System, Telecommunication System, Computer and Electrical Engineering and the IEEE Systems Journal. He has also published three edited/authored books with International/National Publishers. He has guided many students leading to M.E./M.Tech and guiding students leading to Ph.D. He is an Associate Editor of IJCS—Wiley and Security and Privacy Journal—Wiley. His current interest includes Wireless Sensor Networks, Fog Computing, Smart Grid, IoT, and Blockchain Technology. He was invited as Guest Editors/Editorial Board Members of many International Journals, invited for keynote Speaker in many International Conferences held in Asia and invited as Program Chair, Publications Chair, Publicity Chair, and Session Chair in many International Conferences held in North America, Europe, Asia and Africa. He has been awarded best research paper awards from IEEE GLOBECOM 2018, IEEE ICC 2019, and Springer ICRIC-2019.

Challenges Within the Industry 4.0 Setup

Akshi Kumar and Divya Gupta

Abstract

The fourth industrial revolution, which is also known as Industry 4.0 elucidates future industry improvement patterns to accomplish intelligent production processes, including dependence on CPS or Cyber Physical Systems, development of Cyber-Physical Production Systems (CPPS), and execution of smart factories. The purpose of Industry 4.0 is to manufacture an exceedingly adaptable generation model of customized and computerized items and administrations, with constant communications between individuals, products and devices amid the generation procedure. The "Industrial 4.0" idea was first seen in an article published by the German government as a high-tech policy plan for 2020, in November 2011. "Industry 4.0" rapidly ascended as the German national plan. Industry 4.0 will be a new industrial revolution, which will affect global industry. Although it is not a simple and straightforward aspect to accomplish Industry 4.0, and is presumably going to take at least a couple of years to figure it out. Right now, Industry 4.0 is an aspiration, since it incorporates various perspectives and challenges, including logical, infrastructural, financial, social and legal difficulties. This chapter presents challenges of Industry 4.0 related to the practical aspects, infrastructure requirements, cyber security and business models.

Keywords

Industry 4.0 · Cyber Physical Systems (CPS) · Sustainability

A. Kumar
Department of Computer Science and Engineering, Delhi Technological University, New Delhi, India
e-mail: akshikumar@dce.ac.in

D. Gupta (✉)
School of Computing Science and Engineering, Galgotias University, Noida, Uttar Pradesh, India
e-mail: divyagupta@galgotiasuniversity.edu.in

1 Practical Aspects of Industry 4.0: A Case Study

The industrial development has lasted for several years. However, at this point, the fourth Industry revolution that is also known as Industry 4.0 has emerged in the current era. The concept of Industry 4.0 was originally proposed in 2011 for developing the economy of Germany [1–3]. The transition in manufacturing industry from Industry 1.0 to Industry 4.0 is as follows

- The first industrial revolution was represented by mechanical production plants which were based on water and steam power. It was introduced at the end of the eighteenth century [4].
- The second industrial revolution was represented with the mass labor production which was based on electrical energy. It began towards the start of the twentieth century [5].
- The third industrial revolution with automatic production was based on electronics and web innovation technologies. It was presented during the 1970s [5, 6].
- Now, the fourth or current industrial revolution with the attributes of cyber physical systems (CPS) production and based on diverse range of data and information integration, was introduced in 2011. It is also known as Industry 4.0 [1, 4, 7–9].

The fundamental role of Industry 4.0 by means of digital physical frameworks is to satisfy the dynamic prerequisites of generation, and to improve the adequacy and effectiveness of the whole business. Industry 4.0 incorporates various advancements and related ideal models, including Radio Frequency Identification (RFID), Enterprise Resource Planning (ERP), Internet of Things (IoT), cloud-based assembling, and social product development [2, 10–31]. The objectives of Industry 4.0 are to accomplish more

A. Nayyar, A. Kumar (eds.), *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-14544-6_11

operational effectiveness and efficiency with more automatization.

The key aspects of practical aspects of Industry 4.0 are

- digitization, optimization, and customization of generated products
- automation, robotization and adaptation
- human machine interaction (HMI)
- value-added services and businesses
- automatic data exchange and communication [2, 3, 9]

These attributes are profoundly associated with web technologies and advanced algorithms, and they also show that Industry 4.0 is an industrial procedure of significant value adding and knowledge management [32]. Industry 4.0 supports inter-connection and computerization into the traditional industry [33]. The goals of Industry 4.0 are to give IT-enabled mass customization of manufactured items; to make programmed and flexile adjustment of the production chain; to encourage communication among parts, items, and machines; to apply human-machine interaction (HMI) models; to accomplish smart factories with IoT-empowered optimization. Industry 4.0 conveys innovative changes to supply chains, plans of action, and business processes and models [34].

The fundamentals of Industry 4.0 are interoperability, virtualization, decentralization, real-time ability and service orientation. It assists in providing greater adaptability, decrease lead times and lessen costs. The key major standards of Industry 4.0 incorporate cloud/intranet, data integration, flexible adaptation, intelligent self-organizing, manufacturing process, interoperability, optimization, secure communication, and service orientation [34]. It can be outlined as an incorporated, adapted, improved, service oriented and interoperable assembling process which is related with algorithms, big data, and advanced technologies.

Cyber-Physical Systems (CPS) is a mechanism that is controlled or monitored by computer-based algorithms, tightly integrated with the Internet and its users [1, 35]. Physical and software components are deeply intertwined, each operating on different spatial and temporal scales, exhibiting multiple and distinct behavioral modalities, and interacting with each other in a lot of ways that change with context.

CPS being an advanced and emerging technology proffer promising answer to change the procedure of many existing mechanical frameworks [36]. So, the key advances and standards required for the practical usage and implementation of the Industry 4.0 are: Internet of Things, Big Data, Augmented Reality, Advanced Robotics, Cybersecurity, Simulation, Additive Manufacturing, Horizontal/Vertical Integration and Cloud [1, 37, 38] as shown in Fig. 1.

These nine standards and technologies must be incorporated in the manufacturing process to successfully implement Industry 4.0 [39, 40]. While practically implementing Industry 4.0 in the various applications, one must ensure that these six steps are followed:

Step 1: To get the Definition Right
It is very crucial that all partners must understand what they are planning to achieve. Understanding of the goal is a very important step. Establishing a common understanding of requirements and goals is important to ensure that all stakeholders desire to achieve the same objective.

Step 2: Not to take on too much at once
Adopting a well-ordered strategy guarantees that each of the components of industry 4.0, for example, organizing, machine to machine correspondence and integration with legacy systems, will be considered and tended to in a timely and cost-effective manner. Industry 4.0 can best be accomplished when the organization has the correct dimension of

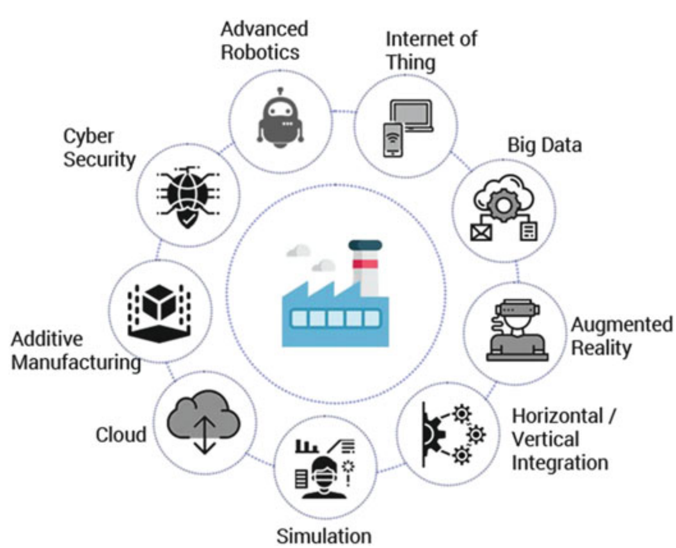


Fig. 1 Key standards and technologies of Industry 4.0

information, certainty and experience—and these are gained in a timely way, ensuring all elements are in place before over-committing resources.

Step 3: Know what you want to achieve

To set a clear target for execution of Industry 4.0 with digitalization and having a full comprehension of what the ultimate objective looks like helps adjusting team members and overcome any potential barriers in the beginning, which implies that the Industry 4.0 can be introduced efficiently.

Step 4: To make sure that all stakeholders are accepting the change

For Business transformation, all stakeholders should be ready to accept the change which is going to be introduced in the process of implementing the Industry 4.0 standards. They should understand and acknowledge the requirement and the changes which are going to be introduced, and should know how they are adding value to it. Each stakeholder should understand their responsibility towards the achievement of goals, according to the experience they have and the skills they possess.

Step 5: To Establish the Business Model

Industry 4.0 does not imply only the transformation in technology but it also proffers a chance to contemplate and design new business models. An unambiguous and intelligible business model plays a very important role in implementation and it provides a clear path for progress. For stakeholders, including employees, clients and providers, the usage of a business model provides the knowledge and understanding of the business model process and its important aspects. The development of digitalization-based business models influences organizations across three vital areas:

1. Optimization—Digitalization can enhance an existing business model. For instance, the utilization of RFID/GPS to follow the constant status of modules throughout the entire inventory network.
2. Exchange—Taking an effective business model starting with one industry and applying it then onto the next, where it was not implemented previously. For example, load sharing resources between factories/businesses, in a similar fashion to the way in which car sharing works.
3. Development of New models—Traditional business models are replaced by new business models which provides the opportunity for truly disruptive change [9, 41].

Step 6: Assess Technical Readiness and Maturity

To assess the technical readiness and maturity, one should consider the current state of digital infrastructure which can underpin a wide range of manufacturing activities related to products including integrating sensors and monitoring performances.

To introduce and implement Industry 4.0 in any manufacturing industry, these steps are essential. But achieving and fulfilling all these steps while practically implementing Industry 4.0 is strenuous and prolonged activity.

Early adopters are starting to implement the Industry transformation by taking small steps. They are beginning with pilot projects and are acquiring knowledge before reapplying the techniques on an extensive basis. To fully embrace the digital transformation journey, the understanding of the opportunities being created through technological developments is necessary.

Furthermore, various practical applications of Industry 4.0 technologies have been identified and classified into four categories, which are represented as follows:

1. Decision support and decision-making
   Industry 4.0 has the capability to improve decision support and to proffer more automated decision-making with the new and advanced technologies. The new possible methods to collect and analyze information from procedures and products can adequately give extraordinary advantages for manufacturing logistics, as executives can base decisions on what is really occurring on the shop floor of a production facility.
   In addition, this can permit automating decision-making, contrasted with conventional ERP frameworks, which customarily just provides decision support. Industry 4.0 innovations additionally guarantee the presentation of artificial intelligence and increased augmented reality in assembling, providing a new way of decision support and decision-making. For decision support and decision making, the following components of Industry 4.0 are implemented.
   – Artificial intelligence
   – Big data analytics
   – Augmented and virtual reality

Practical applications of decision support and decision making are:

- Retailers in UK and USA:
  – Tesco uses the above-mentioned components of Industry 4.0 for their precise promotions and strategic grouping of existing and potential consumers.
  – Amazon employs the concept to deliver the accurate recommendations for their consumers.
  – Walmart uses decision support in supply-chain optimization.
- Biopharmaceutical industry, USA:
  – The biopharmaceutical industries have reduced their process flaws by modifying the target process corresponding to the statistical analysis. It has also

eradicated the yield variation by increasing its vaccine yield by more than 50%.

- Remote monitoring application for heavy-duty automobiles, USA:
  - The application exploited AI to predict the health status of the diesel engine of the automobile components by employing classification models to diagnose the analogous engine behavior and fuzzy logic based algorithms to determine and predict remaining life of the components.

2. Identification and Interconnectivity
   Industry 4.0 is all about making everything smart. To be a smart machine, it should have relevant data and information sharing in order to identify and analyse the work done. To achieve this, the system must have interconnectivity between them, and that's what forms the Internet of Things. Automated Identification technology is being implemented commercially since a long time. Now with Industry 4.0, one is able to network information about processes and products in a supply chain and within a production facility. With the use of IoT, everything within a facility can be connected, which really helps in increasing the productivity and to analyse the status of the equipment for any faulty reasons. One can properly utilize all the resources using IoT and thus have new ways of implementing better business model with a goal of servitization. For identification and interconnectivity, the following components of Industry 4.0 are implemented.
   - Sensors
   - Auto ID
   - Networking technology

Practical applications of identification and interconnectivity are:

- Communication sector in China,
  - Various aspects and features of different devices for instance wireless sensor networks, IoT, machine to machine and CPS are integrated and analyzed, to delimit the difficulties related to the CPS design.
  - Machine-to machine home networks were also reviewed.
- Water Distribution networks in USA,
  - It utilized the simulated processes to exhibit the operative performance and interaction of Cyber Physical networks by enabling CPS modeling.
- IoT based gateway systems in China,
  - With help of IoT, the telecom operators were able to transmit and analyse data.
  - Sensor networks were also connected via IoT.
  - This improved data transmission and also assisted in upgrading the data and topology display.
- Soil and Water monitoring in Taiwan, China
  - The monitoring of systems has been improved efficiently using ICT
  - Agricultural environmental risk zones are focusly classified and treated accordingly

3. Seamless Information Flow
   This ensures the future factory has a well-formed communication with the various subsystems. It is important to have a highly digitized and vertically integrated factory to have real time information and seamless data flow to make the decision which in turn improves the production planning and control activities. For seamless information flow, the below mentioned components of Industry 4.0 are implemented.
   - Real-time planning and control
   - Integration of IT systems
     - Cloud manufacturing

   Practical applications of seamless information flow are:

- Healthcare industry in UK
  - Incorporating cloud computing development in the life sciences
- Software, IT sector in UK
  - Highlighting future, importance and uniqueness of cloud computing assisted in analysing the strengths of cloud computing.
- Education, India
  - Defining the advantages and usefulness of employing cloud computing for students. This has proffered opportunities for the students to comprehend, experiment and innovate.

4. Robotics, Automation and New Production Technology
   Additionally, mechanization and usage of robots, can have incredible implications for future smart factories. Robotization can be considered as one of the primary patterns and is expected to impart improvements in the Industry 4.0 idea. One part of computerization identifies with assembling hardware, which will be described by the use of very mechanized machine instruments and robots. For Robotics, Automation and new production technology, the following components of Industry 4.0 are implemented.
   - Industrial robots
   - 3D printing
   - Automatic guided vehicles

Practical applications of automation, robots and production technology are:

- Healthcare and Social applications, USA
  - The utilization of automation and robots helped in enhancing the human life quality and in analyzing

potential societal impacts by facilitating ambient intelligence, extensive communication and enhanced processing abilities.

- Tata Motor, India
  - Manufacturing of cars is fully automated using robotics and testing of cars utilizes robots as well as automation.
  - This has improved customer satisfaction.
- Usage in Autonomous vehicles, USA and Germany
  - Parallel programming model was proposed for CPSs which guaranteed timely completion of real time processes.

2 Infrastructure Requirements

The design principles of Industry 4.0 help designers to transit manufacturing industries into smart factories using Industry 4.0. The six principles of Industry 4.0 are modularity, interoperability, decentralization, virtualization; service orientation and real-time capability (responsiveness) [42, 43] are described as follows:

P1. Modularity: This principle is associated with the structure of system components. Modularity can be illustrated as the capacity of framework segments to be isolated and joined effectively and rapidly. A system can be distributed into multiple modules that are loosely coupled and can be reconstructed on a plug-and-play methodology. Modular Systems are easy to debug and are flexible with new changes that are going to be introduced in the system according to the customer's requirements.

P2. Interoperability: As modularity comes into place, system components are loosely connected. Sharing technical and business information within system components is ensured by Interoperability. CPS facilitate connection over the IoT and the IoS. Standardized mechanical, electrical and communication data is vital to enhance interoperability. The semantic advances in communication have guaranteed to empower interoperability for the smart factory and thus numerous ontologies have been created.

P3. Decentralization: Framework components like modules and products, will autonomously settle on choices, unsubordinated to a control unit. In these frameworks, employees settle on choices about common issues and alter their processes and methodology as per the business circumstances and conditions. Embedded systems empower self-sufficient CPS to cooperate with their condition by means of sensors and actuators. Such cooperation will adjust procedures to every individual request, empowering minimal effort, and custom-made items.

P4. Virtualization: Dividing a system into multiple modules and establishing communication between them, generates the need to test the system extensively. Thus, to resolve this challenge, virtualization is needed. In this principle, an exact copy of the actual environment is being set up and tested first before handing it to the users. A virtual system is utilized to examine and manage the physical aspects of the actual systems in real time. In addition, it can be used to give training to the workforce, diagnose, predict faults and also to fix them.

P5. Service orientation: Industry 4.0 is more aligned towards selling products and services rather than only selling products. Manufactured Products are sold to the customers at almost no profit or margins. And hence the industries are having a hard time to survive. Industry 4.0 suggests that we need to focus more on services as they can generate better profits. In Smart Factories, manufacturing industries outsource some of their processes and then concentrate on their core process with an aim to have a better productivity. Such a system energizes development in the improvement of core processes in which the assets are focused and won't scatter. Thus, a production industry will promote and trade its core processes as a support of another industry and end up making a profit. CM uses an infrastructure that utilizes the internet as a method for providing and merchandising services, and with cloud computing enables the on-demand provision of services.

P6. Real-time capability (responsiveness): Industry 4.0 implements the interconnectivity between modules in a smart factory. A system should be designed in such a way that it automatically detects the malfunction of any component or failure of any resource. To ensure that, one needs to have data sharing in real time and information should also get processed in real time. The system should be robust enough to know where exactly the fault is or it should provide the possibility of where the fault could be, so that it can be fixed in real time. The system should respond to internal changes, monitoring and controlling in real time. All errors or warning should be detected on time and the system should be robust and capable enough to recover rapidly.

2.1 Requirements of the Industry 4.0

The requirements of the industry 4.0 are widely ranging from tools and machines to workforce, online data control to communication. These requirements are interrelated with the design principles of the industry 4.0 [42, 43]. Thus, one can define the requirements of industry 4.0 in terms of design principles as follows:

R1. Modular machine tools, material handling equipment and decentralized control architecture: Every module in a system should be self-sufficient and act as a whole in its own. Any module can be reconfigured according to the requirements and it should directly connect to the cloud system without having any need of human intervention. Principles 1, 3 and 6 are implemented through requirement 1.

R2. Efficient and Multi Skilled Workforce: Workforce in a smart factory should be efficient and multiskilled. Every person should work on several tasks including supervision, programming or performing a manual process or assembly. Principle 1 is being realized via this requirement.

R3. Standard infrastructure: This implements principle 1 and 6. Standard supply infrastructure should be used in order to connect the system component to all supply layers. Every system component can be provided by different vendors.

R4. Standard communication and CPS: Every layer should communicate via an integration layer so as to implement a standardized communication protocol. Principle 2 is achieved by the means of standard communication and CPS.

R5. Embedded computer: Modularity defines that each module in a smart system has to be autonomous and should be able to take their own decisions based on the information retrieved through cloud computing via CPS. Thus, they must have an embedded computer. Embedded computer requirement realizes the principle 2 and 3.

R6. Secure communication: Information sharing in cloud computing should be authenticated with access requests. This requirement is in accordance to principle 2.

R7. Virtual system builder: Every physical system should have a virtual system builder that operates as an engine for the virtual system which enables effective simulation. Principle 4 is being achieved through the Virtual system builder requirement.

R8. Core Processes as service: Principle 5 is associated with this requirement. It states that the factory can provide its principal functions to external manufacturing plants or to other internal production lines.

R9. Cloud connection and computing: A system should be able to access the requirement of service suppliers and customers. And the product service should be shareable via cloud computing. Principle 5 and 6 are related with requirement 9.

R10. Online data analysis, monitoring and control: A system should provide real time data which should be accessible online or via cloud to monitor the status of the system without physically present at the system. This requirement implements principle 6 of Industry 4.0.

R11. Healability: As Principle 6 suggests, a system should be robust enough to detect and heal from all the disturbances in real time.

Other than these requirements, the Industry 4.0 requirements can be further classified into two parts as follows [44]:

1. Production perspective
2. Data center perspective

Production Perspective

The production perspective gives rise to a range of IT infrastructure requirements based on the fundamental principles illustrated in Table 1. Hardware and machine controllers are encapsulated inside an area that communicates with the outside world by means of data interfaces. These enclosures must have a constant and reliable power supply and also require adequate and fitting atmosphere control. These compounds must be monitored in terms of criteria such as humidity, temperature and access. In certain conditions, there are other security necessities that additionally should be considered (protection category, fire extinguishing system, and so on.).

Data Center Perspective

The same fundamental principles apply to IT infrastructure in the data center environment (as shown in the Table 2). The compounds (IT racks) contain switches, servers and storage systems that need to have a reliable power supply. These sensitive devices require appropriate cooling systems to keep them within a specified temperature and humidity range. Operating parameters, statuses and alarms all require careful monitoring. Protection from physical dangers (access, fire, smoke, dust, water, etc.) is also crucial.

3 Cyber-Security and Legal Issues

The fourth industrial revolution which is referred as Industry 4.0 has emerged in the present era. This industry revolution has changed the course of human history. Industry 4.0 integrates information technology and operational technology. It consists of data driven production systems; Internet of Things or cyber physical systems to be precise. With Industry 4.0, the interconnected era also dawns. An association between different users (i.e. customers and employees) and systems is proffered via interconnection. Thus, business performance is expedited and new opportunities are generated by collaboration on a shared platform [45]. Cloud provides a common platform on which data can be stored and users from

Table 1 Production perspective of Industry 4.0 requirement

Production perspective
• Real-time data processing
• Accessibility, redundancy
• Safeguarding against failure
• Field level, IT level
• Protocols
• Interfaces
• Investment cycles
• New technologies (cyber-physical systems, big data)

Table 2 Data center perspective of Industry 4.0 requirement

Data center perspective
• Performance
• Accessibility, redundancy
• Security (software-related, physical)
• Functionality
• Scalability
• Innovation cycles
• New technologies (big data, Web 3.0, Internet of Things)

different locations can collaborate. Industry 4.0 interacts with huge amount of information, creating human machine association frameworks and enhance the communication between the computerized and physical environments. This new wave of internet enabled technologies in manufacturing industry has increased data density which brings new challenges, especially cyber security [46, 47].

Cyber security is the prime concern that all legislatures considers with utmost priority. It is an assurance of business data and valuable information regarding a subject or framework in digital shape against unapproved access, abuse and misuse. Cyber-attacks and cyber risks have expanded hugely in the most recent times. Any stakeholder that utilizes IoT frameworks is directly or indirectly influenced by this issue. Particularly large organizations are vulnerable to maleficent and hostile assaults that outcome in genuine financial troubles with tremendous misfortunes, for example, information debasement, framework crashes, security ruptures, glory, client, reliability and market misfortunes [48].

With growing system associations, cyber-attacks have turned out to be increasingly inclined to abuse of information for various objectives such as economic and prudent reasons. With boom of this recent innovation, the number of potential assailants are expanding and their strategies are becoming advanced, complex, more refined and effective. In this manner, it should be secured against dangers and vulnerabilities so as to accomplish the most noteworthy capability of IoT.

In this section one of the mainstream subjects of current times, cyber security is being discussed. The security threats of IoT, fundamental reasons of cyber-attacks, cyber security requirement and some cyber security measures in detail are also discussed.

3.1 Security Vulnerabilities

The security vulnerabilities are related to the different layers of the IoT architecture. But there is no single universally accepted architecture for Internet of Things. Different researchers have proposed various architectures. In general, the Internet of Things layered architecture can be classified into four major layers as follows [47, 49]:

1. Perception (Sensing) layer: The perception layer is the first layer of the IoT architecture. It is also known as Sensing Layer. This layer consists of physical objects and the detecting gadgets, for example, different types of tangible innovations, RFID sensors. These sensory technologies permit devices for perception and detection of different objects.
2. Network layer: System layer (Network layer) provides the framework to assist remote and wired associations between the data processing frameworks and the sensor devices.
3. Service layer: Service layer is used to manage services that are essential and required by the clients or the applications. This layer is linked to the database and is accountable for the service management process.
4. Application layer: Interface layer (Application layer) consists of collaboration techniques with clients or applications. This layer is accountable for conveying application services to the client.

The components utilized at each layer and the security threats related to them are described in Table 3 [50]:

On each layer, the security threats are different due to the different features and functionalities of each layer [47].

As at the sensing layer, the smart sensors automatically sense and recognize the environment and exchange information among gadgets. Therefore, most of the threats occurs due to external elements, mainly from sensing and other information gathering devices [51, 52]. Common threats of the perception layer are as follows:

– Unauthorized access: Unauthorized accesses are prominent dangers because of physical or rationale assault.
– Confidentiality: Assailants can put malignant sensors and gadgets to obtain data from the framework.
– Availability: Sometimes the framework is physically or logically captured and thus the system does not work.
– Noisy data: At times, the data contains partial and incorrect information when transmitted over networks covering vast distances.
– Malicious code assaults: Using malicious code like virus and Trojan, attackers cause software failures.

The system layer associates everything in Internet of Things and carries a huge amount of data. It is therefore

Table 3 Security threats and vulnerabilities by level

S. No.	Layer	Components	Security threats
1	Perception Layer	Barcodes, RFID tags, RFID reader-writers, Intelligent sensors, GPS, BLE devices	Unauthorized access, Confidentiality, Availability, Noisy data, Malicious code attacks
2	Network Layer	Wireless sensor networks (WSNs), WLAN, Social Networks, Cloud Networks	Denial of Service (DOS), Routing attack, Transmission threats, Data breach, Network congestion
3	Service Layer	Service management, Database, Service APIs	Manipulation, Spoofing, Unauthorized access, Malicious information, DoS attacks
4	Application Layer	Smart applications and management, interfaces	Configuration threats, Malicious code (Malware) attacks, Phishing Attacks

sensitive to attacks [52, 53]. Following are the security threats at this level:

– Denial of Services (DoS) attacks: Denial of Service attacks are the most frequent threats. In DoS attack, the attackers continuously post failure messages and fake requests on the targeted network [54, 55].
– Routing attack: Routing attacks are related with the routing path of the message. In this, the attackers alters the directing data, create routing loops and send error messages.
– Transmission threats: Transmission threats includes blocking, interrupting and information exploitation.
– Data breach: Data breach is the liberation of secure and confidential data, intentionally or unintentionally, to an untrusted source and environment.
– Network congestion: Network congestion may occur due to various sensor information with various gadget verification in a network system.

The service layer facilitates correspondence and management of information in applications and services. It also assists and contains the services utilizing application programming interfaces (APIs). The data security is critical in this layer as compared to other layers. A few of the security dangers of this layer are:

– Manipulation: Manipulation is the alteration of the information by the attackers.
– Spoofing: In spoofing the attacker masquerades as another source and gain illegitimate access to falsify the information. This occurs due to the lack of adequate authentication control mechanisms [54].
– Unauthorized access: Abuse of services as they are being accessed by unapproved clients.
– Malicious information: Privacy and security of data are jeopardized with pernicious tracking [54].
– DoS attacks: Useful and important service and assets are made inaccessible to legitimate users by imposing false requests and exposing it to traffic beyond its normal capacity. Mirai botnet, Brickerbot and the Repeater botnets are some of the high profile IoT botnets that are used for DoS attacks [54, 55].

The uppermost layer from which the user interacts is the application layer. The application layer consists of interfaces and applications [52, 53]. The security threats of application layer are as follows:

– Configuration threats: Configuration threats includes failing configurations at interfaces and false misconfiguration at remote hubs.
– Malicious code attacks: Malicious assaults are made to the product framework directly to sabotage the expected behavior of the framework.
– Phishing Attacks: In these attacks, the assailants try to get sensitive data such as usernames, passwords, credit card details.

The security prerequisites at all layers are confidentiality, integrity, accessibility, validation, non-repudiation and protection. These prerequisites are discussed in detail in later sections.

3.2 Evolution of Cyber Attacks

The digital world is continuously changing and advancing due to the change in technologies, the intricacy of the assailants, the value of potential targets and the impacts of assaults. With the extensive use of networking in manufacturing industries, hackers have exploited network-based services for suspicious plans. It is crucial to understand the security and privacy concerns entirely to apply security controls to systems properly. Addressing security objectives appropriately will allow the risks to diminish [47]. This implies that following the principles of security is essential to ensure that the cyber security is attained completely.

Cybercrime is triggered by advanced and revolutionary technologies. Cyber security demands safety against a wide scope of difficulties. It is getting difficult with new innovations, technologies, trends in mobile usage, online networking, great wall-financed and methodical foes and 24 h assaults. Cybercrimes directly affect companies and organizations. From affecting the stock trade rate to brand reputation, everything is on stake now.

The following Fig. 2 shows the evolution of cybercrimes over the years.

Towards the beginning of the 1980s, the digital assaults started with password cracking and secret word speculating strategies. Today, the crimes have evolved and started occurring via packet spooling, advance scanning and refusal of service. In future, the digital assaults are predicted to destroy vital focus centres using bots, morphing and pernicious codes. Over the period of time, the behavior of digital assaults has transformed from being simple to advanced, complicated and sophisticated.

3.3 Cases of Cyber-Attacks

The cyber world is a continuously developing network where everyone can connect with each other independently of time and distance via the networking services. Due to this reason, attackers utilize the digital world for their own benefits targeting people, organizations, banks and even military and government offices. Some of the digital assaults are being discussed as follows:

- Flame: Skywiper, Flamer or Flame, is a modular PC malware found in 2012 as a virus. It assaulted Microsoft Windows working framework PCs in the Middle East. At the point when assailants utilized Flame as a digital weapon for spying, it damaged other frameworks through a local area network (LAN) and gathered private data. Skype and other audio conversations, console action, screenshots and computer display contents, stored files, contact information and network traffic were recorded. Flame is reported as most sophisticated and complex malware ever found. It is also believed that Flame was operating since August 2010. Flame infected 1000 machines including government organizations and educational institutes. Iranian Oil Ministry computers was its main target. The virus was discovered by Iranian National Computer Emergency Response Team (CERT), CrySys Lab and the MAHER Center of Kaspersky Lab, on May 28, 2012 [47].
- July 2009 Cyber Attacks: Some digital assailants released botnet and attacked prime government and business websites, of the United States and South Korea. This was done by capturing the computers which further overloaded the servers by traffic flooding. It is estimated that more than 3 laks PCs were seized from various locations. White House, The Pentagon, Ministry of Defense and National Intelligence Service were among the affected websites. The attacked caused disruption rather than stealing the data [47].
- Steel mill attack: The programmers assaulted a steel mill in Germany on December 2014, utilizing booby trapped emails to capture logins that gave them access to the plant's control system. Assailants entered into the steel factory's corporate system using spear-phishing and social engineering. The plant's production network was then reached from this network. Parts of the plant failed which in turn led to failure of control components and all manufacturing appliances were cut off. Thus, the blast furnace could not be legitimately closed, resulting in the massive damage [47].
- Operation Ghoul: SFG malware, found in an European energy company network in June 2016, has made an indirect access for focused mechanical control frameworks. As per security specialists at SentinelOne Labs, the objective was to extract information from the power network or to halt the power network. Windows-based SFG malware was made to conquer conventional antivirus programs and firewalls.
- New York Dam Attack: In March 2016, PC based control of a dam in New York was confiscated by aggressors utilizing cellular modems.
- Ukrainian Power Outage: In December 2015, a power organization situated in western Ukraine endured a power blackout that affected a vast territory that including

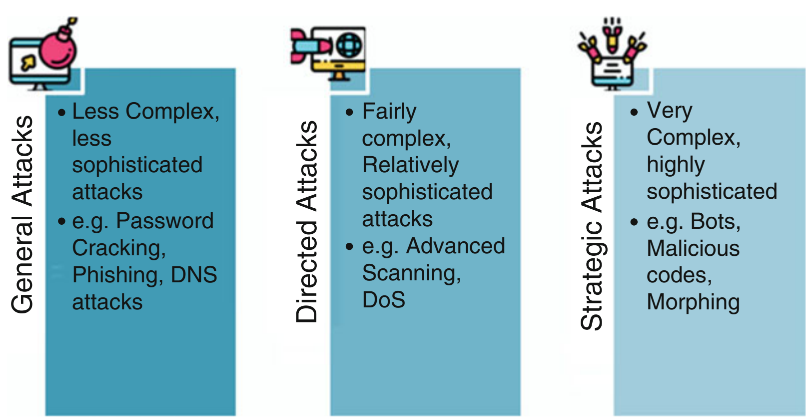


Fig. 2 Evolution of cyber attacks

the provincial capital of Ivano-Frankivsk. Three different energy organizations, known as "Oblenergos", were assaulted and obstructed the power of 225,000 users. The assault was done by programmers who utilized BlackEnergy malware that misused the macros in Microsoft Excel report. The bug was transplanted in the company's network through spam messages [47, 54].

The assaults on industrial frameworks will be persistent due to the increased mechanization and web association. This implies the quantity of such destroying digital assaults proceed to rise and along these lines all the harmed associations will pay an overwhelming cost for the assaults.

3.4 Strategic Principles of Cyber Security

The essential security standards of an efficient IoT security are addressed from six aspects. These standards must be guaranteed for security to be ensured in the whole IoT framework [47, 56, 57].

– Confidentiality: The capacity to conceal data from individuals who are unapproved or unauthorized to use that data is known as confidentiality. The data thus needs security from unapproved access. It is significant security highlight in IoT. In most of the situations, private user information, government data and military secure data and credentials should be avoided from unapproved disclosure.
– Integrity: Data integrity defines the data shielding from unapproved, unforeseen or inadvertent modifications. Trustworthiness is an obligatory security property as a rule so as to give dependable services to IoT clients.
– Availability: Availability is defined as the access to the data required by a client or a gadget whenever needed. In this way, the IoT assets must be accessible on a timely basis to address issues or to avoid significant misfortunes.
– Authenticity: Authentication enables only the approved entities to carry out specific tasks in the system. Diverse system confirmation requires distinctive arrangements. The authenticity property enables only the approved entities to perform specific activities in the system network. Some authentication requires strong control authenticity while some need moderate passwords authentication systems.
– Nonrepudiation: The property of nonrepudiation introduces certain proof in situations where the client or gadget can't deny an activity, for example, payment activity. IoT administration must give a believed review trail for establishing trust.
– Privacy: The extent of interference of a system with its attributes and environment along with the level to which it shares individual data to other people is determined by the degree of privacy it provides.

3.5 Cyber Security Measures

Cyber security measures must be taken to restrict digital dangers [47]. Some essential cyber security measures that could forestall any possible assault are discussed as follows:

– Never permit the machines to associate directly to a machine on a business network. Organizations might not be aware that any such association network exist, but a digital assailant could find this gap and exploit mechanical control frameworks to cause physical harm.
– A firewall is a program that filters approaching and active traffic between various parts of a network. Try not to enable a risk to the system framework by lessening the quantity of routes in the network and applying security conventions to the routes.
– Remote access to a system utilizing some moderate techniques like Virtual Private Network (VPN) gives enormous points of interest to the end clients. The remote access can be fortified by diminishing the quantity of IP addresses that can get to it by utilizing system gadgets or potentially firewalls to identify IP addresses.
– Role-based access control authorizes or decline access to network resources dependent on business capacities. This confines the capacity to get to files or framework parts that clients or aggressors ought not have the capacity to get to.
– Having solid passwords is the most effortless approach to fortify the security. Programmers can utilize programming devices that can effectively increase unapproved access. As indicated by Microsoft, you ought to definitely abstain from utilizing individual information, (for example, date of birth), in reverse known words, and character or number successions that are near one another on the console. Make a secret key strategy to enable workers to screen best practices for security.
– It is imperative to guarantee attention to fix and updates. Organizations ought to consider refreshing framework and programming settings naturally to abstain from missing basic updates.
– The representatives of an organization are in charge of guaranteeing the security of the business. It is critical to give the representatives awareness about safe online practices and training.
– Due to the versatile nature, there is a more serious danger of smart gadgets. Encoding your workstation is the least demanding approach to avoid potential risk.
– Nevertheless, Firewalls, interruption recognition and counteractive action sensors and logs from the servers

ought to be observed regarding faults indications. A viable digital safety effort will confine the harm, increment the trust of accomplices and clients, and lessen recuperation expenses and time.

As new frameworks and associated environment for connected devices keeps on developing, security budgets are bound to increase exponentially for every organization.

The fate of the digital security strongly relies upon considering threat landscapes and developing patterns in technologies based on big data, IoT and cognitive computing.

3.6 Legal Implications for Industry 4.0

Other than offering plenty of opportunities, Industry 4.0 could likewise be viewed as a concern for the numerous dangers present where choices are made by systems and not by people. The disruptive technologies of Industry 4.0 desire access to large volumes of information. Ineffectively drawn laws and government arrangements can obstruct gainful access without diminishing the dangers exhibited by Industry 4.0. The advances in manufacturing industry raise significant moral and security concerns that could dissolve trust if not addressed keenly. Endeavoring to wed something as specialized as Industry 4.0 with strong guideline displays new difficulties. The further developed Artificial Intelligence become, the more they become "secret elements", where the maker of the AI framework does not by any stretch of the imagination known on the premise on which the AI is settling on its choices. In this way, guaranteeing responsibility and consistency in AI conduct turns out to be troublesome. The administrative systems should have the capacity to satisfactorily oversee and control the hazard in Industry 4.0-based items, administrations and methodologies. These dangers, and the capacity to manage them, are a test both for the organizations concerned and the controllers entrusted with securing customer interests and the integrity of the administrative and legal system. Controllers, in general, will adopt a technology-neutral strategy to rule-making, concentrating on activities and their results rather that the methods of delivery. Subsequently, on a fundamental level, strategies for performing existing exercises or accomplishing existing results should fall perfectly inside existing lawful and administrative structures. If this methodology works, then there is no requirement for new laws or guidelines, simply new understandings of plans of action and business models, or hazards, and of the viability of risk management systems. However, the introduction of self-sufficient non-human on-screen characters in Industry 4.0 decision making process procedures could offer elevation in complex inquiries with respect to the risks.

Licensed innovation: The idea of protected innovation rights as would be tested in the time of Industry 4.0. One field where this is as of now happening is AI. A key thought for organizations trying to utilize AI in their business is the manner by which they can ensure their investment into AI. Licensed innovation is not only concerned with just calculations on which the AI model is based, but also ideas or developments that are made by AI.

Copyright: Most jurisdictions ensure the outflow of the algorithms and AI process in the form of software through copyright. Nonetheless, there is a bigger challenge where the AI keeps on learning and thus make changes to its very own product structure. By what means should controllers react in such manner: would it be a good idea for them to perceive copyright in works made by AI, and the responsibility for works? For example, the idea of computer authorship is authorized in UK law: if the work is PC produced, the creator will be the individual by whom the courses of action fundamental for the production of the work are attempted. This definition is worthy when a specialist plans a straightforward calculation and effectively inputs a given arrangement of information with the motivation behind inspiring the production of another PC program. Be that as it may, how would it be extended for progressively complex situations that include multifaceted models that are fit for learning and growing without human supervision? Thus, all these situations effects inquiries of possession, duty, and responsibility.

Obligation: Issues relating to civil and criminal risk would turn out to be progressively significant in fields, for example, operability, ecological assurance, and wellbeing and security.

4 Development of New Business Models

With the emergence of Industry 4.0, the manufacturing industry has seen massive transformations. Industry 4.0 which is represented with aspects of operational excellence have brought new wave of innovation [58].

This rapid digitization have consequences for the way companies offer value to clients, their competitive position in the market and thus their business model.

The existing business models need to be reconsidered to integrate the technological innovations in the business models [41]. Thus, the development of new business models is realized with the emergence of industry 4.0, which is being discussed in this section.

4.1 Features, Challenges and Requirements of the Industry 4.0 with Respect to Business Models

Industry 4.0 has upended traditional ways of doing business. Advances in technology, connectivity and manufacturing have changed the way the products and services are consumed. As a result, designers are incorporating new technologies like automation, augmented reality, virtual reality and cloud computing to meet customer expectations driven by the same. Thus, the business models are evolving and with them the requirements for the business models have also evolved. The business models require more efficient ways to merge technologies into the product life cycle [59].

The following Table 4 summarizes the principal features of Industry 4.0 and key issues that affects the traditional business models. It also describes the requirements to face the digital transformation [60, 61].

4.2 Various Methodologies Influencing Business Models

In the following section, different methodologies that respond to the features of Industry 4.0 and challenges to face digitization are discussed. Each method focuses on a specific issue, yet they all are interrelated. Methods such as service-oriented method, network-oriented method and user-driven method are described below.

1. A Service-oriented method
   Industry 4.0 is pushing towards selling infrastructures as service as well as products, so a new approach of Hybrid model is needed. Mixing Product with service business has been recognized as Hybrid model. Apart from this, business model, which were only into digital industries until now, are now becoming applicable to traditional product-based industries. Now with industries moving towards a Service approach by outsourcing their services does not have to particularly depend upon manufacturing cost to make profits. The result is alleged product-service system (PSS) concept, it describes a hybrid model which offers a specific product-service bundle as a solution with more integrated development and realization of the system [59, 62, 63].
2. A network-oriented method
   New Approaches are arising in the market and the existing approaches are changing constantly. The need to introduce new approaches or to introduce a change in existing one is because the horizontal and vertical integration of the value chain and the associated interoperability diversifies firms' traditional boundaries due to the organization and the stakeholders' network. As a result, better methodologies for making and offering value through ecosystems that goes past individual value chains are raising. Due to competition, conventional manufacturing industries that were aligned towards product sales are now more aligned with the ideas of Industry 4.0 [59, 63].
3. A user-driven method
   This method creates new ways to make manufacturing increasingly receptive to user driven design and to adjust it better with consumer value creating processes and contexts. In this approach, organizations should be capable for both learning about their customers and becoming a better ecosystem far from individual value chain. A Company can learn about their customers by promoting evidence-based decision making, and with obtaining more information about the customers using digital tools. Industry 4.0 provides opportunities to focus more on customer demands and to build a more promising and prominent relationships with the stakeholders as well. Besides, an upgraded customer introduction is shown by the extension of creative administration advertising [58, 59, 64].

4.3 Four Different Ways to Direct the Digital Transformation in Manufacturing Companies

The theories explaining innovation levels and the frameworks based on the Business model definitions are examined to explore the implications of Industry 4.0 in Business Model innovation. In this way, four different ways to implement the innovative digital transformation in

Table 4 Main features of Industry 4.0 and main issues that affects the traditional business models

Industry 4.0 features	Traditional business model issues	Digital transformation requirements
Interoperability	Networking and reduction of barriers	Standardization
Virtualization	Flexibility and personalization	Work organization
Decentralization of decision making	Individualized mass production	Availability of products
Real-time capability	Local production	New business models
Service orientation	Low price	Know-how protections
Modularity	Smart goods and services	Availability of skilled labour
	Fragmentation of the value chain	Research investment
	Globalization and decentralization of production	Professional development
	V-H integrated production systems	Legal frameworks
	Automation	
	Human Ingenuity	

manufacturing industries have been identified according to the changes applied to different levels and different elements of the business model to transform all elements of business model to a better one.

A Business Model describes "the rationale of how an organization creates, delivers, and captures value". Every proposition is depicted in this way, demonstrating the change in the value creation (core function and partnerships), value delivery (mixture of services and products offered, communication and sales) and value capture (revenue and cost gained by the firm).

1. Optimization of Internal and External Processes
   This approach represents an incremental innovation that improves the current business without making any big changes. The changes that are introduced are in the form of new modules with new technologies such as big data, additive manufacturing, augmented reality, which optimize the value creation architecture, increasing its productivity and efficiency by reducing the cost, time, employee dependencies. This is the first step to introduce industry 4.0 standards in traditional manufacturing companies. This approach has the lowest risk as one is not making any changes in the already working process. Changes are introduced in business model components to accomplish the advancement of internal and external procedures [59]. The following Table 5 elucidates the outcomes in terms of value creation, value delivery and value capture, by introducing changes via this approach in the traditional business model.
2. Improvement in Customer Interfaces
   This idea is focused on improving the value delivery. Values provision through product and service offering, customer relationships, customer segments. With the presentation of new technologies like Big data and cloud computing, allows us to understand the customers' needs and better customer experiences. After optimizing internal and external processes, this approach could add more value to the conventional business [59]. Table 6 explains the outcomes by introducing changes in business model components to accomplish improvements in customer interfaces.
3. Introduction of New Ecosystems and Value Networks
   This model focuses on improving the core business (core activities of the company), and sharing the issues with other companies and learning new required skills and resources which are needed because of the introduction of new technologies like virtual reality, cloud computing and big data. In this way, companies value creation is linked with partners processes, which establishes an ecosystem rather than individual value creation, which in turn increases the stakeholder's knowledge. This approach requires a change in many business processes like core activities, customer relationships with both customers and stakeholders, resulting in new ways of capturing values [59]. (Table 7).
4. Introduction of New Business Models: Manufacturing Smart Products and Services
   In comparison to other models, this model suggests a whole different business model which is based on new technologies like big data, cloud computing, embedded systems, that offers new and innovative goods and services. This model introduces changes in almost every business element, which provides the opportunity for the business to expand in markets. As this approach is not related to traditional business model, it can be implemented in parallel to working business models. With this approach, companies could experience better

Table 5 Outcomes of optimization of internal and external processes

Value creation
• Product and resource traceability • Machine to Machine connections • Employee training • Data driven decision making
Value delivery
• More Flexible Offers; Individualized mass production, customizations etc.
Value capture
• Cost optimization due to more efficient processes and use of resources

Table 6 Outcomes of improvement in customer interfaces

Value delivery
• Segmentation based on data analysis • More Direct, closely, efficient and long-term relationships • Improved digital sales
Value creation
• Management of new touchpoints • Data collection, monitoring and interpretation • Development of new services
Value capture
• Cost Saving • New revenue streams: dynamic pricing, pay-per-use, online payment etc.

Table 7 Outcomes of introduction of new ecosystems and value networks

Value creation
• Business infrastructure connected to key partners infrastructures • Real time information about production, inventories, status, availability of personnel, etc.
Value delivery
• Access to new customer segments • Broader offering of products
Value capture
• Potential increase in value capture due to cost reduction for all stakeholders

Table 8 Outcomes of introduction of new business models: manufacturing smart products and services

Value delivery
• Smart Products • Innovation in associated services • Co-creation • Direct relationship
Value creation
• New Physical, human and intellectual resources are needed
Value capture
• New revenue streams: dynamic pricing, pay-per-use, performance-based revenues etc.

performance as to the current model and can experiment in new model while the other one still provides revenues [59]. The outcomes of this model are illustrated in Table 8.

As discussed, the main goals of Industry 4.0 have been fulfilled and to understand the concepts and the effect of Industry 4.0 in Business models, one must have a better knowledge of possible advancements that can be applied to traditional business models through Industry 4.0. Three different Industry 4.0 approaches to get close to Industry 4.0 standards are networked ecosystems, service orientation and customer orientation. A set of features, requirements and issues which have been acknowledged to implement Industry 4.0 are discussed. Introducing industry 4.0 in traditional business models enables the identification of different ways to transform them into a better model. Majorly emphasizing on creating value due to both products and services is defined. Valuing customers and aligning more towards their needs makes a better value. Also, there is a need to understand the role of value in new ecosystem, how it should be perceived and created, and should be broken down to approaches and ways, and then analyzed to understand the different ways to help the discovery driven process of new Business models.

5 Addressing the Challenges

The individual technologies that form the components of Industry 4.0, have been in development for quite a while. But their integration with these individual technologies have been in development for some time, their integration with industry frameworks prompts new benefits as well as challenges [54]. In this section the prime challenges of Industry 4.0 are being discussed.

1. Data Challenge
   Industry 4.0 is purely based on data and its analytics, it generates data in different ways and analyze it according to the requirements. In production environment, different types of data is collected via different sources like machine sensors, product data, plant data, quality data, infrastructure data, and logistics data, all of these contribute in data size. Such data faces various challenges and demands various methodologies for storing, processing and management of such data. To overcome these challenges new algorithms, products and models are required to use and gain the benefits of data. Engineers are required to break down such data and to discover relationship between data streams and to increase new bits of knowledge from the information which were not thought before. There is an issue in which a large amount of data is stored or exchanged via emails, excel sheets, printouts on which is very difficult to keep track and analyze the data. Data could be stored in heterogeneous database solutions between various departments. Major problem is data redundancy, with all these sources of information merging into a single place, a big amount of data get redundant. Engineers have to face a big challenge to rectify it. Primitive software's which were getting used in the organization might not be compatible with the data standards of the future generation and data might get lost. Inconsistent data leads to incorrect decisions [8, 41].
2. Data Exchange with Partners
   Companies outsource their core functions which in turn exposes the data to the partners to whom they have outsourced to. They have to exchange data inter department to keep their processes optimized. This is a trend that Industry 4.0 emphasis on sharing their processes and infrastructure as a service to other companies for revenue gain rather than selling only a product. Data transparency is required at this point as other companies might get hands on the data of the company selling their infrastructure to them. Companies might have to share their progress status of some of the products manufactured at their factory for future aspects if needed. Shop floor and ERP level integration is often missing. Traditionally it is not very practical to exchange data in real time and independently, which creates a gap between both things. There's often a delay in data transfer. Sometimes, the physical product is transferred on the conveyor belt but the information to carry out operations on the product doesn't get updated, which results in higher cost. Normally in a production facility, a product has only three stages, production started, in progress and finished, which are not well integrated with ERP systems. So it's a big challenge to have a proper communication and data transfer [8].
3. Training and Skill Development
   Industry 4.0 requires modern and multi skilled staff which is a major challenge, majorly because of aging population and currently working staff are very reluctant to change. Most people who used to work in production are retiring without transferring any production knowledge to anyone else. Other major issue is young staff wants more perks and frequent promotions and frequent in changing jobs. As most of the staff includes old people, they are working in a routine since many years and do not want to learn new technologies. New machines, gadgets and technologies are

very difficult to be introduced to them. This is a major challenge as Industry 4.0 is based on eminent change [8].

4. Process Flexibility
Industry 4.0 ensures modular and process flexibility, which is a challenge in implementation. Such individualization and customization require flexibility at a production level. Currently used technology at the production facility is inadequate and not capable enough to achieve flexibility. Traditionally, systems used at production level are made modular and isolated with time and after introducing several changes. Management changes are hardest to introduce in a production facility. Introducing a change in a traditional process impacts a lot of dependencies in the system and handed over in form of printouts or emails. Usually each change is introduced department wise without any predefined standards and makes the system more complex and cost taking. There is a need of standardization and synchronization between all of the modules of a production facility to achieve flexibility in an effective manner [8, 41, 65].
5. Security
Security is a major concern in Industry 4.0 standards and for the future of industries. Industries need to ensure their people, product and production facilities environment secure from security risks. Using smart devices in production is trending which is a good advantage to ease our lives but it also has a higher security risk. A smart device can be monitored on the basis of hardware and software, which is often ignored. All devices including industrial machines should be updated with time so as to get secure against potential threats which are arising on a daily basis. Keeping a track of every update for every machine is a hectic task. IoT devices are only capable of a small processing power, so a new set of tools and guidelines are required to make the device secure. A cloud connected device is vulnerable to get hacked. A simple virus can enter from any smart device to any production environment and can affect the product which will result in major product returns, heavy fines and reputation loss [8, 41].

6 Challenges to Achieve Sustainable Development

Industry 4.0—the fourth modern industrial revolution, is changing how the universe of business operates. This new revolution is not only the method for creation and structure of items, procedures and associations, but also the incorporation of different new on-screen characters like artificial reasoning, programming, and people into the manner in which society and business work.

With these quick transitions of organizations, another environment is being created. One with progressively effective assembling methods, shared modern systems and advanced inventory network processes and another towards structure and execution of generation. So, there ought to be the topic of how the practical improvement of manufacturing industries fits with the concept of sustainable development.

Sustainable development (SD) is defined as the idea of living, working and developing as a society, while saving the planet at least in its present condition. Sustainable development is a fundamental aspect of economic development in all nations [66]. The balance between the need of humankind to create and the longing to not pulverize the planet in the process is continuously addressed. With the new models that Industry 4.0 has presented to the world, and with the consistently growing opportunities for innovations, generation, and improvement of the manner in which organizations work, the subject of sustainability stands. So, in this section the interrelationship between Industry 4.0 and sustainable development is being discussed.

6.1 Challenges for Sustainable Development

Despite the fact that challenges for SD could be characterized from numerous viewpoints and methodologies, it would be preferable to acknowledge sustainable development challenges by the UN's General Assembly's Resolution and Agenda on Sustainable Development. In 2015, the UN defined 17 noteworthy objectives with 169 goals as the real objectives to "end destitution, secure the planet, and guarantee success for all" by 2030. These objectives are classified into five noteworthy classes: People, Planet, Prosperity, Peace, Partnership [67-69] as highlighted in Fig. 3.

The challenges to accomplish the set objectives in these classifications differ. Few objectives are unachievable for the span of time whereas some are wide in degree and requires far more prominent measures of activities. Other significant difficulties for the accomplishment of the objectives are: absence of substantial leadership (to motivate not only strategy change, but also investment, incorporation, awareness, and mobilization towards the objectives), an understanding of the fundamental tones of the objectives (which means a general move in the manner individuals work, produce, devour, and invest their energy), as well as unification of some of the objectives of all nations (for instance, setting universal benchmarks for clean water, clean air, and so forth). Some of the key difficulties in the method for accomplishing the SD objectives are absence of access to data of governments, low quality of prioritizing the present goals, along with the lack of capacity of governments to confront the size of the SD objectives. Government find numerous troubles in accomplishing the objectives of sustainable development due

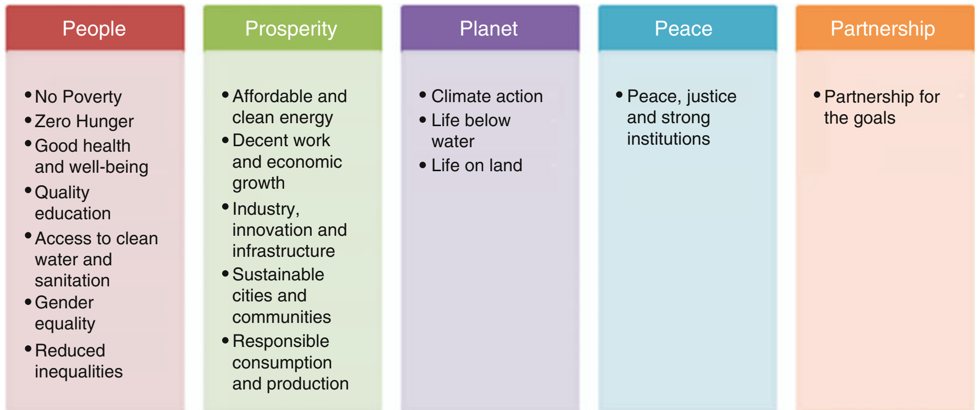


Fig. 3 Categories of challenges of sustainable development

to the absence of organized and boundless information universally. Without that information and without the required capacity of governments, to try and even plan effectively the necessities of their residents to get nearer to the goals, the targets cannot be accomplished. Another approach to see the objectives is with the objective to lead the planet and every one of its occupants to a superior reality and better future.

6.2 Practical Solutions of Sustainable Development Challenges

The developments identified with the rise of Industry 4.0 can be associated with the challenges of sustainable development. The future prospects lies in the integration of Industry 4.0 and the sustainable development as shown in the Fig. 4.

The sustainable development challenges can be overcome with the assistance of the technologies of the Industry 4.0.

As Industry 4.0 embodies interconnectivity, it makes sense that more than one of its components would provide a possible solution, mainly in collaboration with others.

Robotics emerged with virtual prototyping and augmented reality as its corresponding components. Although the computational forces of autonomy and mechanical innovation can make various decisions, but virtual prototyping in this setting can play out the developed situations for simpler decision making. On the contrary, Augmented reality, will make a much more clear picture of the current state, and will sparkle a light on the profundity of the potential outcomes and make the extent of the objectives unambiguous for the policy producers.

Big data and analytics add to the boundless opportunities for data gathering and data analyzing. When implemented accurately even as a stand-alone tool it can be a way to settle a portion of difficulties; particularly the absence of access to data and unified standards. SD goals can get prioritized with the enormous data gathered via approaches inherited in Industry 4.0, along with virtual prototyping which can also help in creating an easy-to-utilize course strategy according to their location, or the state their country is currently in, and to have a better understanding of the circumstances they are facing.

System integration can be very helpful in growth of limits of government and also to gather and integrate data from a wide range of sectors which should be more coupled and consistent yet they are not. System integration will bring standard unification, transparency and accessibility of data across the border.

At last, cloud technologies are cost effective and more accessible, and also creates numerous processes which improves capacity, are simpler, faster and more effective. Cloud technologies develops a lot of new opportunities to achieve effective and efficient SD goals. It provides a wide and affordable solution which can be unified globally and thus makes a standard for information processing, awareness rising, etc.

The following Table 9 presents the potential industry 4.0 solutions corresponding to the sustainable development challenges.

Procedures and opportunities are yet not totally accessible to governments for the accomplishment of the sustainable development objectives, that remains a challenge for all countries. Besides, realizing an answer for the lack of significant initiative and inspiration, the only option is that people

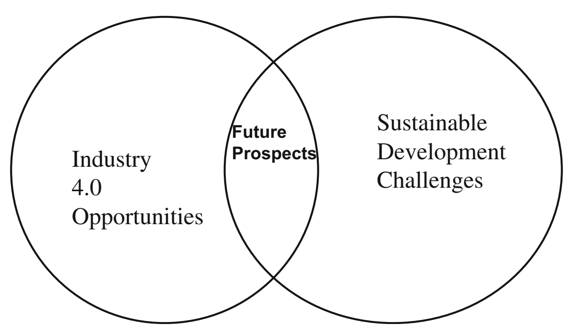


Fig. 4 Opportunities and future prospects of sustainable development challenges

Table 9 The potential industry 4.0 solutions corresponding to the sustainable development challenges

SD challenge	Potential Industry 4.0 solutions
Phrasing of objectives: Vagueness, highly optimistic targets etc.	Robotics, Modeling and simulation technologies (for e.g. virtual processing)
Scope of goals	Robotics, Augmented reality, Big data and Analytics
Absence of comprehension of objectives	Robotics, virtual Prototyping
Absence of unified benchmarks	System integration Cloud technologies Big data and analytics
Lack of access to information	Big data and analytics System integration Cloud technologies Augmented reality
Low quality prioritizing	Virtual prototyping Big data and analytics

handle the challenges of sustainable development on their own with the help of the innovations in technology. As of now there are instances where advancements of Industry 4.0 helped in improving societies, in increasing efficiency, in better interconnectivity and finally at sustainable development.

The fate of Sustainable development has begun to unfurl through the possibilities which Industry 4.0 is proffering.

Some of the examples are discussed as follows:

1. The work done by Rebecca Portnoff used machine learning and artificial intelligence which with the help of algorithms have gathered and analyzed information that helped in recognizing a sex trafficking ring. This work is without a doubt in resonant with the objectives of the sustainable development [70].
2. Another example of Industry 4.0 that aids in improving human lives and wellbeing is achieved with the means of augmented reality and artificial intelligence. In this system the patients with coronary illness are diagnosed and an estimate about their future condition is predicted via the system. This is accomplished with the assistance of the historical information and chronicled information for the particular patients. Based on the investigation the specialists can prescribe better treatment to patients and can also enhance the chances of patients to live. This innovation may be translatable to a more extensive extent of health abnormalities [69].

These two examples depict that components of Industry 4.0 are assisting in accomplishing the goal “Good health and well-being” of the category “People” of the 17 main objectives of sustainable development.

In general, there is no denying that Industry 4.0 is the future for many aspects of life, including sustainable development. The numerous ways associated with increasing abilities of innovation and the creativity of humans can realize innumerable doors for development and achievement in accomplishing human’s defined objectives. More than that—the future has already begun to evolve and is transforming rapidly, including more parts of life and showing greater signs for consideration of the future.

As it is known that the principles and components of Industry 4.0 have the basic purpose of increasing the automation and efficiency of creating products and services. The fourth industrial revolution brought new talent and innovation to the manufacturing industry. This transformation made it feasible to accumulate and analyze data across machines, empowering faster, more flexible, and more efficient procedures to create higher quality goods at reduced costs. It has increased productivity, shifted the economics of many countries, has fostered industrial growth and altered the profile of the workforce. Thus, the sustainable development challenges like decent work and economic growth; industry, innovation and infrastructure; sustainable cities and communities; and responsible consumption and production are being met. As examined, there are numerous prospects, which are already being investigated in this direction. However, the next greater challenge is to find not only a probable solution to achieve the other objectives of sustainable development, but also the required time span to test and integrate many of the potential solutions.

References

1. A. Petrillo, F. De Felice, R. Cioffi, “Fourth Industrial Revolution: Current Practices, Challenges, and Opportunities,” pp. 1–20.
2. M. K. Wyrwicka and B. Mrugalska, “‘INDUSTRY 4.0’—TOWARDS OPPORTUNITIES AND CHALLENGES OF INDUSTRY 4.0,” no. January, 2018.
3. M. Crnjac and N. Banduka, “From concept to the introduction of Industry 4.0,” no. January, pp. 0–10, 2017.
4. M. Kiss, G. Breda, and L. Muha, “Information security aspects of Industry 4.0,” *Procedia Manuf.*, vol. 32, no. January, pp. 848–855, 2019.
5. C. Paper and D. Vuksanovi, “INDUSTRY 4.0 : THE FUTURE CONCEPTS AND NEW VISIONS OF FACTORY OF THE FUTURE DEVELOPMENT,” no. October, 2017.
6. S. Vaidya, P. Ambad, and S. Bhosle, “Industry 4.0 – A Glimpse,” *Procedia Manuf.*, vol. 20, pp. 233–238, 2018.
7. F. A. Coda, R. M. D. Salles, F. Junqueira, D. J. S. Filho, J. R. Silva, and P. E. Miyagi, “Big data systems requirements for Industry 4.0,” *2018 13th IEEE Int. Conf. Ind. Appl. INDUSCON 2018 - Proc.*, pp. 1230–1236, 2019.
8. A. Khan and K. Turowski, “A Perspective on Industry 4.0 : From Challenges to Opportunities in Production Systems,” no. IoTBD, pp. 441–448, 2016.

9. F. Bordeleau, E. Mosconi, and L. A. De Santa-eulalia, “Business Intelligence in Industry 4.0 : State of the art and research opportunities,” vol. 9, pp. 3944–3953, 2018.
10. F. Baena, A. Guarin, J. Mora, J. Sauza, and S. Retat, “Learning Factory: The Path to Industry 4.0,” *Procedia Manuf.*, vol. 9, pp. 73–80, 2017.
11. J. Posada *et al.*, “Visual Computing as a Key Enabling Technology for Industrie 4.0 and Industrial Internet,” *IEEE Comput. Graph. Appl.*, vol. 35, no. 2, pp. 26–40, 2015.
12. Rameshwar, R., Solanki, A., Nayyar, A., & Mahapatra, B. (2020). Green and Smart Buildings: A Key to Sustainable Global Solutions. In Green Building Management and Smart Automation (pp. 146-163). IGI Global.
13. Singh, S. P., Nayyar, A., Kaur, H., & Singla, A. (2019). Dynamic Task Scheduling using Balanced VM Allocation Policy for Fog Computing Platforms. Scalable Computing: Practice and Experience, 20(2), 433-456.
14. Kaur, A., Gupta, P., Singh, M., & Nayyar, A. (2019). Data Placement in Era of Cloud Computing: a Survey, Taxonomy and Open Research Issues. Scalable Computing: Practice and Experience, 20 (2), 377-398.
15. Singh, P., Gupta, P., Jyoti, K., & Nayyar, A. (2019). Research on Auto-Scaling of Web Applications in Cloud: Survey, Trends and Future Directions. Scalable Computing: Practice and Experience, 20 (2), 399-432.
16. Singh, S. P., Nayyar, A., Kumar, R., & Sharma, A. (2019). Fog computing: from architecture to edge computing and big data processing. The Journal of Supercomputing, 75(4), 2070-2105.
17. Pramanik, P. K. D., Pareek, G., & Nayyar, A. (2019). Security and Privacy in Remote Healthcare: Issues, Solutions, and Standards. In Telemedicine Technologies (pp. 201-225). Academic Press.
18. Pramanik, P. K. D., Nayyar, A., & Pareek, G. (2019). WBAN: Driving e-healthcare Beyond Telemedicine to Remote Health Monitoring: Architecture and Protocols. In Telemedicine Technologies (pp. 89-119). Academic Press.
19. Das, S., & Nayyar, A. (2019). Innovative Ideas to Manage Urban Traffic Congestion in Cognitive Cities. In Driving the Development, Management, and Sustainability of Cognitive Cities (pp. 139-162). IGI Global.
20. Nayyar, A., Jain, R., Mahapatra, B., & Singh, A. (2019). Cyber Security Challenges for Smart Cities. In Driving the Development, Management, and Sustainability of Cognitive Cities (pp. 27-54). IGI Global.
21. Nayyar, A., Puri, V., & Nguyen, N. G. (2019). BioSenHealth 1.0: A Novel Internet of Medical Things (IoMT)-Based Patient Health Monitoring System. In International Conference on Innovative Computing and Communications (pp. 155-164). Springer, Singapore.
22. Nayyar, A., & Nguyen, G. N. (2018). Augmenting Dental Care: A Current Perspective. Emerging Technologies for Health and Medicine: Virtual Reality, Augmented Reality, Artificial Intelligence, Internet of Things, Robotics, Industry 4.0, 51-67.
23. Batth, R. S., Nayyar, A., & Nagpal, A. (2018, August). Internet of Robotic Things: Driving Intelligent Robotics of Future-Concept, Architecture, Applications and Technologies. In 2018 4th International Conference on Computing Sciences (ICCS) (pp. 151-160). IEEE.
24. Nayyar, A., Ba, C. H., Duc, N. P. C., & Binh, H. D. (2018, August). Smart-IoUT 1.0: A Smart Aquatic Monitoring Network Based on Internet of Underwater Things (IoUT). In International Conference on Industrial Networks and Intelligent Systems (pp. 191-207). Springer, Cham.
25. Nayyar, A., Mahapatra, B., Le, D., & Suseendran, G. (2018). Virtual Reality (VR) & Augmented Reality (AR) technologies for tourism and hospitality industry. International Journal of Engineering & Technology, 7(2.21), 156-160.
26. Puri, V., Nayyar, A., & Raja, L. (2017). Agriculture drones: A modern breakthrough in precision agriculture. Journal of Statistics and Management Systems, 20(4), 507-518.
27. Nayyar, A., & Puri, V. (2017). Comprehensive Analysis & Performance Comparison of Clustering Algorithms for Big Data. Review of Computer Engineering Research, 4(2), 54-80.
28. Anand Nayyar, E. (2016, November). Vikram Puri,“. In Smart Farming: IoT Based Smart Sensors Agriculture Stick for Live Temprature and Moisture Monitoring using Arduino, Cloud Computing & Solar Technology”[Online], Conference: The International Conference on Communication and Computing Systems (ICCCS-2016), November.
29. Nayyar, A. (2011). INTEROPERABILITY OF CLOUD COMPUTING WITH WEB SERVICES. International Journal of ElectroComputational World & Knowledge Interface, 1(1).
30. Nayyar, A. (2011). Private Virtual Infrastructure (PVI) Model for Cloud Computing. International Journal of Software Engineering Research and Practices, 1(1), 10-14.
31. Nayyar, A., & Puri, V. (2016). Data glove: Internet of things (iot) based smart wearable gadget. British Journal of Mathematics & Computer Science, 15(5).
32. R. Development, “Industry 4.0 and Urban Development The Case of India Bernhard Müller/Otthein Herzog acatech MATERIALIEN,” no. February 2016, 2015.
33. J. Lee, H. Kao, and S. Yang, “Service innovation and smart analytics for Industry 4.0 and big data environment,” *Procedia CIRP*, vol. 16, pp. 3–8, 2014.
34. Y. Lu, “Journal of Industrial Information Integration Industry 4.0 : A survey on technologies, applications and open research issues,” *J. Ind. Inf. Integr.*, vol. 6, pp. 1–10, 2017.
35. A. Sanders, C. Elangeswaran, and J. Wulfsberg, “Industry 4. 0 Implies Lean Manufacturing : Research Activities in Industry 4.0 Function as Enablers for Lean Manufacturing,” vol. 9, no. 3, pp. 811–833, 2016.
36. M. Gyorffi, “Digitising Industry (Industry 4.0) and Cybersecurity.”
37. R. Schmidt, M. Michael, H. Ralf-christian, C. Reichstein, P. Neumaier, and P. Jozinovi, “Industry 4.0- Potentials for Creating Smart Products : Empirical Research Results,” vol. 2, pp. 16–27, 2015.
38. C. Salkin, M. Oner, A. Ustundag, and E. Cevikcan, “A Conceptual Framework for Industry 4.0,” pp. 3–23, 2017.
39. C. A. Havle and C. Ucler, “Enablers for Industry 4.0,” *ISMSIT 2018 - 2nd Int. Symp. Multidiscip. Stud. Innov. Technol. Proc.*, pp. 1–6, 2018.
40. A. Moktadir, S. M. Ali, S. Kusi-sarpong, and A. A. Shaikh, “process safety and environmental protection,” *Process Saf. Environ. Prot.*, 2018.
41. A. Khan and K. Turowski, “A Survey of Current Challenges in Manufacturing Industry and Preparation for Industry 4.0,” pp. 15–27.
42. H. Alkhalefah, “Requirements of the Smart Factory System : A Survey and Perspective,” 2018.
43. D. Gorecky, S. Weyer, A. Hennecke, and D. Zühlke, “Design and Instantiation of a Modular System Architecture for Smart Factories,” *IFAC-PapersOnLine*, vol. 49, no. 31, pp. 79–84, 2016.
44. “Whitepaper: IT and IT infrastructure in the context of Industry 4.0 Bernd Hanstein, Rittal.”
45. Frost & Sullivan, “Cyber Security in the Era of Industrial IoT,” 2017.
46. S. Bligh-wall, “Industry 4.0: Security imperatives for IoT — converging networks, increasing risks,” vol. 1, pp. 61–68, 2017.
47. B. Ervural, “Overview of Cyber Security in the Industry 4. 0 Era Overview of Cyber Security in the Industry 4.0 Era,” no. September 2018, 2019.
48. M. Dawson, “Cyber Security in Industry 4.0 : The Pitfalls of Having Hyperconnected Systems,” no. November, 2018.
49. P. Sethi and S. R. Sarangi, “Internet Of Things: Architecture, Issues and Applications,” *Int. J. Eng. Res. Appl.*, vol. 07, no. 06, pp. 85–88, 2017.

50. A. Varghese and D. Tandur, "Wireless requirements and challenges in Industry 4.0," pp. 634–638, 2014.
51. H. Suo, J. Wan, C. Zou, and J. Liu, "Security in the internet of things: A review," *Proc. - 2012 Int. Conf. Comput. Sci. Electron. Eng. ICCSEE 2012*, vol. 3, no. March, pp. 648–651, 2012.
52. S. A. Kumar, T. Vealey, and H. Srivastava, "Security in internet of things: Challenges, solutions and future directions," *Proc. Annu. Hawaii Int. Conf. Syst. Sci.*, vol. 2016–March, pp. 5772–5781, 2016.
53. Inayat Ali, Sonia Sabir, and Zahid Ullah, "Internet of Things Security, Device Authentication and Access Control: A Review," *Int. J. Comput. Sci. Inf. Secur. (IJCSIS),* vol. 14, no. 8, pp. 456–466, 2016.
54. N. Tuptuk and S. Hailes, "Security of smart manufacturing systems," *J. Manuf. Syst.*, vol. 47, no. November 2017, pp. 93–106, 2018.
55. L. Barreto, A. Amaral, A. Santana, P. Afonso, A. Zanin, and R. Wernke, "Network and information security challenges within Industry Costing models," *Procedia Manuf.*, vol. 13, pp. 1253–1260, 2017.
56. G. D. Rodosek and M. Golling, "Cyber Security : Challenges and Application," pp. 179–180, 2013.
57. M. Abomhara and G. M. Køien, "Cyber Security and the Internet of Things : Vulnerabilities, Threats, Intruders," vol. 4, pp. 65–88, 2015.
58. C. ARNOLD, D. KIEL, and K.-I. VOIGT, "How the Industrial Internet of Things Changes Business Models in Different Manufacturing Industries," *Int. J. Innov. Manag.*, vol. 20, no. 08, p. 1640015, 2016.
59. J. Ignacio, "Business model innovation through Industry 4.0 : A review," *Procedia Manuf.*, vol. 22, pp. 4–10, 2018.
60. K. D. Thoben, S. A. Wiesner, and T. Wuest, "'Industrie 4.0' and smart manufacturing-a review of research issues and application examples," *Int. J. Autom. Technol.*, vol. 11, no. 1, pp. 4–16, 2017.
61. M. Maslarić, S. Nikoličić, and D. Mirčetić, "Logistics Response to the Industry 4.0: the Physical Internet," *Open Eng.*, vol. 6, no. 1, pp. 511–517, 2016.
62. E. Fleisch, M. Weinberger, and F. Wortmann, "Geschäftsmodelle im Internet der Dinge," *HMD Prax. der Wirtschaftsinformatik*, vol. 51, no. 6, pp. 812–826, 2014.
63. M. M. A. Iivari Petri; Komi, Marjaana; Tihinen, Maarit; Valtanen, Kristiina, "Toward Ecosystemic Business Models in the Context of Industrial Internet," *J. Bus. Model.*, vol. 4, no. 2, pp. 42–59, 2016.
64. M. Ehret and J. Wirtz, "Unlocking value from machines: business models and the industrial internet of things," *J. Mark. Manag.*, vol. 33, no. 1–2, pp. 111–130, 2017.
65. Y. Zhang, T. Qu, O. Ho, and G. Q. Huang, "Real-time work-in-progress management for smart object-enabled ubiquitous shop-floor environment," *Int. J. Comput. Integr. Manuf.*, vol. 24, no. 5, pp. 431–445, 2011.
66. T. Stock and G. Seliger, "Opportunities of Sustainable Manufacturing in Industry 4.0," vol. 40, no. Icc, pp. 536–541, 2016.
67. J. M. Müller, "What Drives the Implementation of Industry 4.0 ? The Role of Opportunities and Challenges in the Context of Sustainability," 2018.
68. G. Prause, "Sustainable business models and structures for industry 4.0 JOURNAL OF SECURITY AND SUSTAINABILITY ISSUES," vol. 2, no. December 2015, 2016.
69. R. Tsvetkova, "What does Industry 4.0 mean for sustainable development?", International Scientific Journal of Scientific Technical Union of Mechanical Engineering, Industry 4.0, Vol. 2, Issue 6, pp. 294–297, 2017.
70. R. S. Portnoff *et al.*, "Tools for Automated Analysis of Cybercriminal Markets," pp. 657–666, 2017.

Akshi Kumar is an Assistant Professor in the Department of Computer Science and Engineering at Delhi Technological University (formerly Delhi College of Engineering). She has been with the university for the past 11 years. She has received her Ph.D. in Computer Engineering from Faculty of Technology, University of Delhi in 2011. She completed her Master of Technology with honours in Computer Science and Engineering from Guru Gobind Singh Indraprastha University, Delhi in 2005. She received her Bachelor of Engineering degree with distinction in Computer Science and Engineering from Maharishi Dayanand University, India in 2003. She has presented several papers in international conferences and published work in peer-reviewed and science cited journals. Dr. Kumar has also authored a book 'Web Technology: Theory and Practice' published by CRC Press, Taylor and Francis Group. She is active reviewer of many top journals of IEEE, IET, Springer, Emerald and Elsevier. In addition, she is currently serving as a Guest Editor of Springer Energy Systems. Her research interests are in the area of intelligent systems, user-generated big-data, social media analytics and soft computing.

Divya Gupta is currently working as an Assistant Professor at Galgotias University, Greater Noida. She has received her M. Tech. (Master of Technology) in Software Engineering from Delhi Technological University and B. Tech. (Bachelor of Technology) in Information Technology from GGSIPU. Her research interests include Intelligent Systems, Web Mining and Web-based Software Engineering.