

Advanced Manufacturing and Supply Chain with IoT

*Revolutionizing industries through smart
technologies and connectivity*

Ameya Deshpande

Bidyut Sarkar

Deep Dave

Ravi Dave



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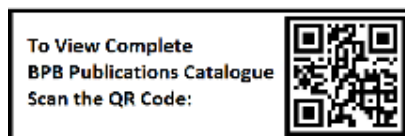
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*Our family members and mentors for their unwavering support and
guidance throughout our journey.*

About the Authors

- **Ameya Deshpande**, a seasoned professional with over eight years of experience, has cultivated a deep understanding of the intricate dynamics that drive complex supply chains and manufacturing systems. His journey at the forefront of innovation, working within organizations such as Google, Cummins, and Lyft, has provided him with a unique perspective. Ameya's strong educational foundation, which includes a Master's degree from Purdue University and a Bachelor's degree in Mechanical Engineering from the University of Pune, has been instrumental in shaping his expertise. Throughout his career, he has meticulously observed the transformative shifts within the consumer electronics and automotive sectors.
- **Bidyut Sarkar** is an IT professional specializing in the Life Science and Industrial Manufacturing industry. Over his 20-year career at IBM, he has developed a blend of industry experience, a comprehensive understanding of AI and Analytics, and strategic solutioning skills. His work has impacted large pharmaceutical companies and industrial manufacturing industries, particularly in the United States. He has been part of efforts to provide IT solutions against counterfeit drugs and implement AI/ML-powered predictive demand and automated replenishment capabilities. Through AI-driven technologies, he has contributed to solutions that enhance cybersecurity and guarantee the authenticity and safety of medications worldwide. His professional experience has taken him to various parts of the world, including the USA, Netherlands, Saudi Arabia, Brazil, and Australia. This multicultural experience has given him insights into global organizational challenges, reinforcing his commitment to addressing critical issues.
- **Deep Dave** is an esteemed digital transformation and IT system reliability expert specializing in **Industrial IoT (IIoT)** and digital strategy. His achievements include pioneering digital initiatives that have transformed manufacturing processes, enhancing operational efficiency and patient care. As a tech influencer, Deep has extended his impact beyond the confines of his immediate professional circle. He has been a voice of authority and inspiration in the digital transformation community, sharing his insights and experiences through various platforms. His passion for knowledge extends to research and academia. He has authored multiple research papers on pivotal topics such as digital transformation, neural manufacturing, Industry 4.0 and 5.0, IT system reliability, IoT, and human-robot collaboration.

- **Ravi Dave** is an accomplished supply chain expert in orchestrating SAP global rollouts, specializing in customized solutions for purchasing, inventory management, and warehousing. With over 12 years of invaluable global supply chain and logistics experience, Ravi's distinguished career has been marked by a relentless commitment to driving digital transformation across various industries, including retail, distribution, consumer goods, manufacturing, automotive, and textiles. As a digital transformation leader, Ravi is profoundly committed to propelling the frontier of innovative technologies. His passion lies in recognizing and harnessing the transformative potential of cutting-edge advancements such as AI, IoT, blockchain, and automation.

About the Reviewers

- ❖ **Balaji M** is a Microsoft Azure IoT Specialty-certified IoT engineer with a Bachelor's in Electronics and Communications Engineering. He has a significant amount of experience in the end-to-end processes of both the hardware and software sections of IoT. His area of expertise is in consumer electronics and automation. Quite recently, he expanded his horizons by stepping into Industry 4.0. His areas of interest include but are not limited to wireless technologies, safety / integrity of systems, low-power devices, data analytics, and ML on edge.
- ❖ **Nishant Krishna** is an entrepreneur, writer, and inventor who loves exploring and using new ways to solve complex problems in cybersecurity, cyber forensics, system programming, cognitive computing, and product scaling to hyper-scale levels.

In his software development career of 23+ years, he has created many products from scratch, working in various technical roles in Architecture, Cybersecurity, API Development, Anti-Counterfeiting Technologies, Cloud and Virtualization, the Internet of Things, and Machine Learning.

In his consulting role, he advises many companies in product development, threat surface reduction, cyber forensics, database, and application scalability, using standard processes for delivering high-quality products.

As an adjunct faculty member in many prestigious educational institutes, he tries to find innovative and hands-on ways to teach complex concepts as part of his teaching assignments.

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Preface

In an era defined by connectivity, data-driven decision-making, and unprecedented technological advancements, this book delves into the pivotal role of the **Internet of Things (IoT)** in revolutionizing how we conceive, produce, and distribute goods.

This book presents an in-depth study of the interaction between advanced manufacturing and IoT, providing priceless insights and useful consulting advice to transform the industrial manufacturing sector.

The principles of IoT in manufacturing, real-world case studies, difficulties and solutions, and the potential of IoT in supply chain management are just a few of the many subjects covered in this book.

Throughout the book, readers will gain a thorough understanding of how IoT improves operational efficiency, enables predictive maintenance, optimizes production planning, ensures quality control, and transforms the supply chain.

This book also equips manufacturing professionals with its pragmatic approach and forward-thinking viewpoint to use IoT to unlock new levels of productivity, competitiveness, and creativity in the constantly changing field of advanced manufacturing.

Chapter 1: IoT Fundamentals, Architecture, and Protocols - The introduction section of the book provides a comprehensive overview of the digital revolution and the ascent of IoT in advanced manufacturing. It explores the origins and pivotal technologies steering Industry 4.0, progressing toward Industry 5.0, characterized by human-machine collaboration. The section traces the evolution and milestones of IoT, detailing the enabling technologies and their transformative influence on industries. The role of IoT in manufacturing is emphasized, showcasing applications in predictive maintenance, production planning optimization, and quality control. Additionally, it examines IoT's transformative impact on supply chain management, focusing on real-time tracking, coordination, collaboration, and demand forecasting.

Chapter 2: Embracing IoT in Manufacturing - This chapter explores the transformative impact of IoT on manufacturing, focusing on real-time monitoring and maintenance with IoT-enabled sensors for predictive maintenance. It covers how IoT improves efficiency in production planning through real-time tracking and agile planning. Quality control is addressed, emphasizing automation, precision, and data analysis using IoT. Integrating robotics and IoT is discussed, covering innovation, safety, and maintenance. Real-world

case studies illustrate IoT applications across various manufacturing processes, showcasing its role in monitoring, production planning, quality control, and robotics.

Chapter 3: The Power of IoT in Supply Chain - This chapter will cover real-time use cases of IoT in the supply chain, empowering stakeholders to boost operational efficiency and decision-making. IoT sensors revolutionize inventory planning by providing real-time consumer behavior data, enhancing forecasting accuracy. IoT sensors monitor chemical usage for inventory replenishment, triggering automatic replenishment orders when levels drop. Advanced data processing and IoT technologies improve delivery tracking, ensuring timely and high-quality product delivery. Asset monitoring with IoT devices enables real-time tracking and management, enhancing quality control, on-time delivery, and forecasting. IoT asset tracking and blockchain technology ensure secure, transparent business transactions across the supply chain.

Chapter 4: IoT: Use Cases in Smart Factories - This chapter reveals the swift transformation of the manufacturing sector driven by the integration of the IoT. It discusses how IoT enhances connectivity among products, machines, and factories through sensors and computers, showcasing its real-time data's transformative impact on innovation, productivity, and responsiveness. Real-world examples demonstrate how IoT optimizes various aspects of manufacturing, from predictive maintenance to supply chain management. The discussion extends to technical and strategic considerations, addressing challenges and offering solutions. Ultimately, the chapter empowers readers to leverage IoT's potential in manufacturing, shaping a future landscape defined by optimization, agility, and automation.

Chapter 5: Business Factors and Optimization for IoT Implementation - In this chapter, we will discuss a variety of subtopics that cover the essential aspects of aligning IoT initiatives with business strategy, conducting cost-benefit analysis, managing risks, project planning and execution, change management strategies, and optimizing IoT processes. Each subtopic gives organizations the insights, methodologies, and strategies to optimize their IoT implementation efforts and achieve business success in the advanced manufacturing sector.

Chapter 6: Challenges and Solutions - This chapter explores challenges in implementing IoT, emphasizing security, privacy, interoperability, and standards. It stresses the need for robust infrastructure, effective data management, and analytics to handle vast data. Power efficiency is crucial, and stable network architecture is required for increased traffic. Integrating IoT with existing systems poses challenges and requires attention to ethical and legal issues. Collaboration among stakeholders is essential to prioritize security, interoperability, scalability, and privacy for responsible IoT implementation.

Chapter 7: Artificial Intelligence in Manufacturing - This chapter explores the dynamic transformation in manufacturing, driven by the integration of AI and IoT, leading to Industry 4.0. It covers applications like predictive maintenance, dynamic scheduling, defect detection, and more, showcasing the broad impact of AI. The chapter emphasizes the essential elements for successful adoption, such as infrastructure upgrades and workforce reskilling, promising increased throughput, cost reduction, and improved quality control. Ultimately, it envisions a future where manufacturing continuously self-optimizes through data-driven learning, marking a significant leap into the digital frontier of excellence.

Chapter 8: The Future of IoT - This chapter explores the potential of IoT in various industries, emphasizing the synergy of predictive analytics and AI for optimizing supply chain and manufacturing processes. A case study demonstrates using AI-driven predictive analytics within an IoT strategy. The intersection of blockchain and IoT is examined through a supply chain and manufacturing case study. The chapter delves into IoT's role in promoting supply chain sustainability, featuring a case study on IoT-powered sustainability efforts. Using a healthcare-focused case study, it explores the interaction of 3D printing and IoT in modern manufacturing. The final section underscores the significance of big data analytics for gaining valuable business insights and making data-driven decisions, emphasizing real-time processing and analysis capabilities when combining IoT and big data technologies.

Chapter 9: Key Takeaways - This chapter concludes the book by summarizing the key lessons learned from the IoT revolution in supply chain and manufacturing. It summarizes IoT's transformative power and impact on various topics, including real-time monitoring, predictive maintenance, production planning, quality control, and supply chain optimization.

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CHAPTER 1

IoT Fundamentals, Architecture, and Protocols

Introduction

The book's introduction thoroughly explores the digital revolution and the ascent of **Internet of Things (IoT)** in advanced manufacturing. It covers the genesis and pivotal technologies propelling Industry 4.0, as well as the shift to Industry 5.0 marked by human-machine collaboration. The segment further probes the IoT's evolution and milestones, encompassing enabling technologies and its game-changing influence on industries. Additionally, it underscores IoT's role in manufacturing, spotlighting predictive maintenance, production planning optimization, and quality control. It culminates by analyzing IoT's revolutionary imprint on supply chain management, particularly in real-time tracking, coordination, collaboration, and demand projection. This chapter covers the essential IoT infrastructure, detailing sensors, controllers, data networks, cloud computing, ERP applications, and data analytics tools. Security's pivotal role is emphasized, addressing data transmission, storage, encryption, access control, compliance, and audits. Powered by batteries, sensors enable diverse monitoring while controllers facilitate local computation and network connectivity. IoT networks link devices to the cloud, where data is processed and stored, and user applications offer visualization and interaction. IoT analytics distills insights from the expanding pool of IoT data.

Structure

The chapter covers the following topics:

- Overview
- The digital revolution: From Industry 4.0 to 5.0
 - Dawn of Industry 4.0
 - Key technologies driving Industry 4.0
 - Industry 5.0: The human-machine interaction
 - Difference between Industry 4.0 and 5.0
- Role of IoT in manufacturing
 - Enabling predictive maintenance
 - Optimizing production planning
 - Enabling quality control
- Role of IoT in supply chain
 - Real-time tracking and tracing
 - Enhancing coordination and collaboration
 - Demand forecasting and inventory management

Objectives

By the end of this chapter, you will learn how to harness different types of IoT technologies for manufacturing. You will gain practical skills to work with IoT components, analyze their data, and appreciate their impact on predictive maintenance, production planning, quality control, and supply chain management. Through hands-on learning, you will explore key IoT concepts, sensor technologies, data networks, cloud computing, and security considerations. This will empower you to comprehend how IoT is transforming the manufacturing landscape.

Overview

The Fourth Industrial Revolution, known as **Industry 4.0**, is causing a transformation in industries across the globe. This revolution builds upon the advancements of the revolution and brings about a new era of interconnectedness automation, machine learning, and real-time data in various industries.

Experts predict that the global Industry 4.0 market is set for growth. By 2026, it is expected to reach a market size of USD 165.5 billion, with a growth rate of 20.6% during the forecast period.¹ Recent data also reveals that the Industry 4.0 market was valued at USD 114.55 billion in 2021 and is projected to reach USD 377.30 billion by 2029 with a growth rate of 16.3%.²

Industry 4.0 is driven by manufacturing techniques, intelligent products, and IoT. This transformative innovation aims to provide real-time data on production, equipment, and component flow; allowing companies to enhance their processes, increase productivity, and gain an edge. At its core, Industry 4.0 leverages the power of IoT to create interconnected networks of devices, sensors, and machines that form systems. These advanced technologies enable data exchange and communication, creating opportunities for decision-making, accurate prediction analysis, and flexible industrial operations. Businesses can increase efficiency, boost product quality, and spark creativity using the IoT's many features.

Industry 4.0 centers around the IoT, the backbone for integrating and connecting components in the manufacturing ecosystem. The IoT enables communication between machines, sensors, and systems by creating a network of interconnected devices that share data and collaborate to make decisions and automate processes.

The impact of Industry 4.0 goes beyond sectors, with significant transformations occurring in supply chain management and manufacturing industries. Traditional practices are challenged as enabled solutions provide end-to-end visibility, traceability, and seamless coordination. By integrating physical systems, smart factories are created where machines interact, optimize themselves, and adapt to changing conditions in time. This results in levels of flexibility and agility.

As we transition from Industry 4.0 to the emerging era of Industry 5.0, a new paradigm is introduced emphasizing collaboration between humans and machines. Industry 5.0 aims to combine the efficiency and precision of automation with creativity and problem-solving abilities. This collaboration is expected to bring solutions that drive advancements in manufacturing, agile production methods, and customer-centric approaches.

It is crucial for organizations that want to remain competitive in the changing landscape of manufacturing to understand the digital revolution and the role of IoT in this evolution. By embracing technologies and utilizing real-time data, businesses can achieve efficiencies, improve product quality, enhance supply chain visibility, and drive innovation.

As we move forward into the phase of supply chain and manufacturing, it becomes apparent that opportunities are waiting to be discovered. However, it is important to acknowledge and tackle the challenges that come with adopting Industry 4.0. Concerns regarding security and privacy complexities surrounding data governance, the readiness of the workforce to adapt to advancements, and the need for infrastructure, all require careful attention.

¹ Industry 4.0 Market Size, Share, Industry Trends & Growth Drivers 2030 (marketsandmarkets.com).

² Industry 4.0 Market Size, Share | Growth Analysis [2022-2029] (fortunebusinessinsights.com).

The digital revolution: From Industry 4.0 to 5.0

We are entering a new era of Industry 4.0, where digital tech and physical systems come together. This change means that automation, the IoT, and **Artificial Intelligence (AI)** are now part of how we make things. Companies are using data and smart analysis to make their work better and make decisions smarter. This move to Industry 4.0 makes businesses work more efficiently, spend less money, and create better products.

Dawn of Industry 4.0

The onset of the revolution, commonly referred to as the Dawn of Industry 4.0, marked a significant turning point in the manufacturing sector. It brought about an era characterized by transformation and technological advancements. This phase completely revolutionized how factories operate, optimize their processes, and interact with their surroundings.

Industry 4.0 stands out because of its features, such as the wide use of sensors, devices, and systems that are all linked and can collect and analyze data in real time. The **Industrial Internet of Things (IIoT)**, which makes manufacturing processes smarter and more automated, is built on this foundation of connectivity and data sharing. The fourth industrial revolution, also known as Industry 4.0 transforms conventional factories into smart factories.

To better grasp the concept behind Industry 4.0, let us consider an example from the manufacturing industry. Imagine a factory that produces goods. In manufacturing settings, production processes typically follow a path and involve human intervention at various stages, throughout the manufacturing cycle. However, as we enter the era of Industry 4.0, this factory will transform.

The factory's assembly line is equipped with sensors integrated into machinery, equipment, and finished products. These sensors collect real-time data on temperature, pressure, vibration, and quality indicators. The data is continuously transmitted to a system for processing, analysis, and generating insights. By leveraging data analytics and AI, the smart factory can enhance its manufacturing processes. **Machine Learning (ML)** algorithms help find trends and outliers in the data so that maintenance can fix machines faster and keep them from breaking down as often. For example, if a sensor detects a temperature increase in a piece of machinery, the AI system can promptly generate a repair request to prevent any potential breakdowns.

Industry 4.0 fosters supply chain collaboration, connecting smart factories with consumers and suppliers digitally for real-time data exchange and demand-driven production. For instance, when demand surges, the system adjusts production and orders materials automatically, ensuring order fulfillment. This transformative technology capitalizes on

networked devices, data analytics, AI, and automation, enabling efficient, flexible, and high-quality factory operations, enhancing a company's competitiveness in the market.

Key technologies driving Industry 4.0

The rapid advancement of technology has brought about an era in manufacturing called Industry 4.0. This revolutionary wave is fueled by a range of technologies that are spearheading the transformation in the manufacturing sector. In this chapter, we will explore the technologies that form the foundation of Industry 4.0 and how they are revolutionizing operations and manufacturing processes. These technologies are at the forefront of reshaping the manufacturing industry, including the IoT, cyber-physical systems, big data analytics, artificial intelligence, robotics, cloud computing, and additive manufacturing. By understanding these technologies and their capabilities, businesses can optimize efficiency, productivity, flexibility, and innovation. This journey will delve into the power and impact of these technologies driving Industry 4.0.

Several vital technologies facilitate the transformation and integration of processes within the production environment to drive Industry 4.0 forward. These technologies are crucial in merging digital systems to enable real-time data collection, analysis, and decision-making. Let us explore some of these technologies that are propelling Industry 4.0.

Internet of Things

The IoT refers to a type of technology that is revolutionizing businesses worldwide. The term *Internet of Things* refers to a network of devices and sensors that are connected to one another and work together to collect, share, and analyze data in real time. These devices can include items like household appliances and wearable gadgets, as well as more complex machinery used in industries and infrastructure.

The main idea behind IoT is to facilitate communication and collaboration between objects and digital systems. By equipping objects with sensors, actuators, and networking capabilities, they become *smart* and capable of generating and transmitting data. This data is then analyzed to gain insights, optimize operations, and make decisions. IoT devices talk to one another and centralized servers by means of wireless and wired connectivity protocols like Wi-Fi and Bluetooth. Because of their connectivity, systems may be monitored, controlled, and automated in real-time, leading to greater effectiveness, output, and adaptability. The IoT encompasses a network where physical objects connected to the Internet can share information through sensors and software for purposes ranging from household products to advanced industrial equipment. Take a look at the following *Figure 1.1*: