EE482 Industrialization: Role of Public and Private Sectors (Section 046401)

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Chapter 11

Transitioning into Industry 4.0

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Introduction

The content, starting from the beginning of Chapter 1, has presented the evolution of industrial development and industrial revolutions. This marked the first-time technology was applied in production, impacting economic and societal structures and fostering economic growth in countries that began using machinery in manufacturing activities. The content across various chapters has shown the significant role industrial development plays in the economic development process to the present day.

This chapter introduces topics extending towards the future, specifically Industry 4.0, presenting the fourth industrial revolution. This involves the integration of machinery with the Internet, enabling machines to generate data from their operations and transmit it through the Internet. This transformation will significantly alter industrial operations in the future. The details of the integration patterns of machinery technology and information technology will be presented in the following sections.

11.1 Fundamentals of Technological Change

Since 2010, the world has undergone significant transformations due to rapid developments in new technologies. The emergence of SMACT components, an acronym for:

- Social networks
- Mobile platforms and apps
- Advanced Analytics and Big Data
- Cloud and artificial intelligence
- Things (Internet of Things)

Innovations have occurred faster than anticipated, such as affordable sensors, smartphones in the pockets of billions, improved battery systems, and self-driving cars.

11.2 Cyber-Physical System

According to a report on European technology trends, it is evident that cyber-physical systems, connecting physical entities with Internet-based systems, have led to changes in daily life and business. This transformation not only affects human-to-human connections but also facilitates data exchange between machines. This includes three categories:

- Human-to-human (h2h)
- Human-to-machine (h2m)
- Machine-to-machine (m2m)

For instance, the management of product transportation can utilize SIM cards, sensors, and GPS, generating extensive data throughout the entire process. This data is transmitted through the Internet and stored in cloud data servers, contributing to the concept of the industrial internet. This change is considered the fourth industrial revolution, following the historical sequence depicted in Figure 12.1. Additionally, advancements in internet-related software, such as web browsers, have enabled complex and diverse functionalities, as illustrated in Figure 12.2. This progress facilitates applications in various areas, including communication, data storage, document handling, and video conferencing.

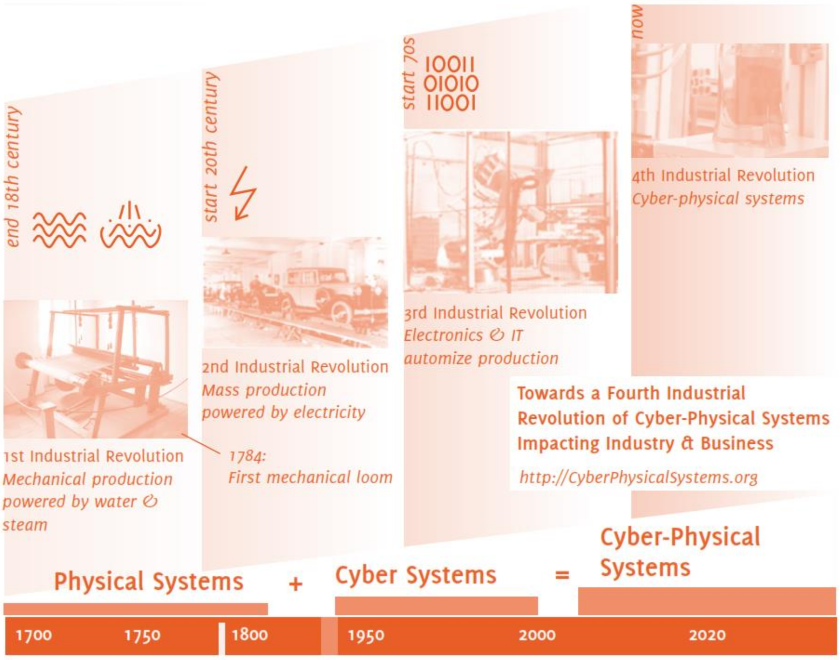

Figure 11.1: Industrial Revolutions 1–4

Source: Bloem et al. (2014)

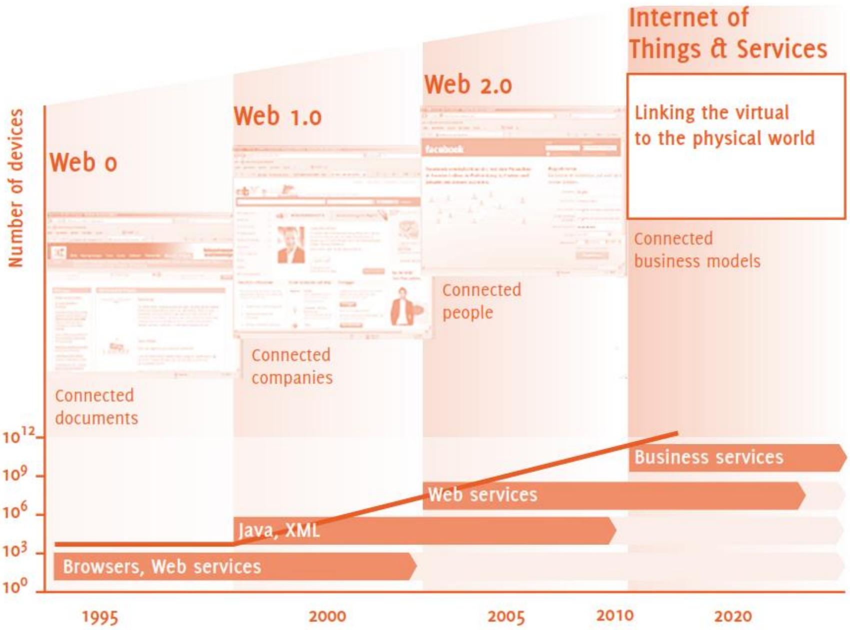

Figure 11.2: Technological Changes in Web Browser Utilization

Source: Bloem et al. (2014)

Industrial Internet, as defined by General Electric, refers to the digital processing technology, sensors, and internet connectivity integrated into all General Electric devices. Many sensors have been installed in jet engines, generating a large volume of data every second during engine operation. All this data is stored and processed using artificial intelligence to enhance the efficiency of future flight engine operations.

This transformation will fill every square meter of factory space with the "Internet of Things (IoT)." Currently, we find ourselves in the early stages of this fourth phase, characterized by "Cyber-Physical Systems" (CPS). These systems result from the integration of production systems with the Internet, emphasizing both the collection of physical data and data processing. Key factors include:

1. Easy, affordable internet connectivity everywhere.
2. Development of sensors detecting various physical data at a low cost and small size.
3. Low-cost large-scale data storage on the cloud.
4. High-efficiency data processing on the cloud.

This change has led to standardization and collaboration through the Industrial Internet Protocol Advantage consortium, founded in 2013. The consortium aims to establish standards for devices and communication systems to connect the entire production sector conveniently, particularly for exchanging and linking data generated during all production processes. The result is a common standard for industrial connection and data exchange called Common Industrial Protocol (CIP), marking the beginning of a new era in the industry.

Currently, the industrial world has entered the fourth stage, or the era of the Internet of Things & Services, expanding rapidly. The characteristics of machinery now include not only physical capabilities, such as cutting, drilling, welding, or moving goods, but also the ability to generate and store data from ongoing tasks. Furthermore, desirable machinery features include the ability to process previously stored data to enhance future production efficiency. This transformation represents the integration of Operational Technology (OT) and Information Technology (IT), fundamentally driven by the development of the Internet of Things (IoT). This allows various devices to connect to the internet.

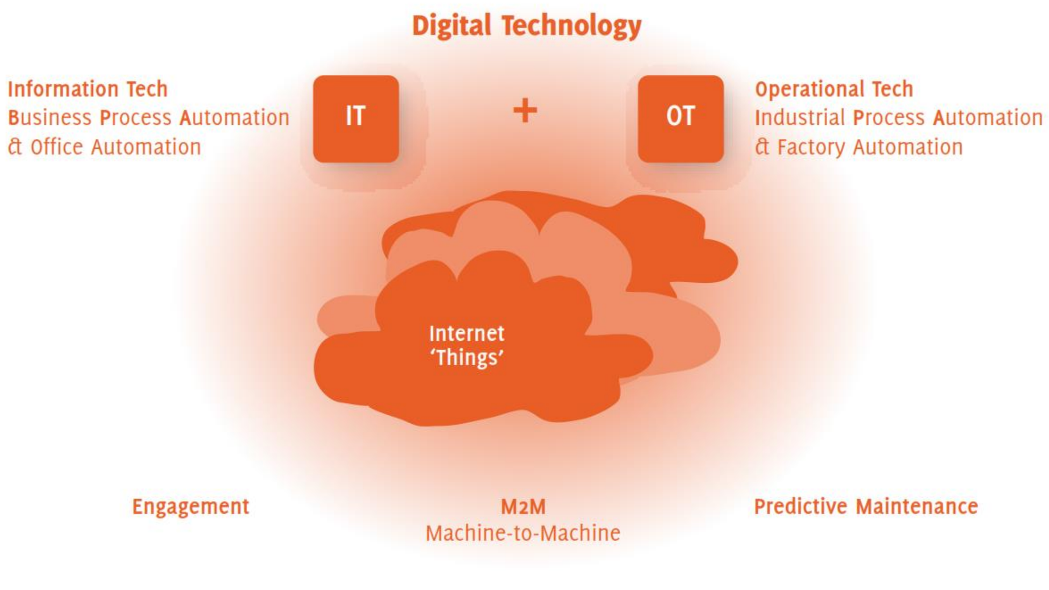

Figure 11.3: Integration between IT and OT

Source: Bloem et al. (2014)

The lack of integration between these two technologies for several decades has led the industrial sector to focus solely on product manufacturing. This transformation has shifted the value of production, emphasizing not only the creation of value from the produced goods but also the generation of valuable data for enhancing efficiency. Therefore, it can be stated that data has become an immensely valuable asset. In various industrial sectors, data generated during production, through detection and storage, has created significant value when continually utilized. When evaluating the value derived from data usage, it is found to be greater than the value of the produced goods.

There are four key factors for the development of Industrial IP utilization:

- **Internet and Communication System Readiness:** Availability of internet and communication systems, with current coverage by 4G and 5G signals in most urban and industrial areas, supporting real-time data communication.
- **Cost of Internet Connectivity and Sensor Price:** Reduced costs of internet connectivity and sensor prices, allowing mass production of sensors and affordable installation
- **Ease of Installation and Operation of the Entire System:** Simplified installation and operation of the entire system, eliminating the need for highly trained engineers.

11.3 Benefits of 3 Aspects of Cyber-Physical Systems Connecting to the Physical World

The industry has three main reasons to increase software and connect machinery to the network in traditional industrial processes. This aims to increase revenue and profits for the business. Machine-to-Machine communication, communicating between machines, reduces human intervention and has significant implications for improving efficiency and elevating safety levels in the manufacturing process. Connecting to information technology systems, especially in machine maintenance, enables the anticipation of repair times using real-time production data. Furthermore, future developments may allow remote maintenance. Increasing customer or consumer involvement by sharing production-related information instills confidence in the quality of the products.

(1) Machine-to-Machine communication

Communication between machines can significantly enhance efficiency and safety, especially when linking various units in the production process. For example, connecting data from manufacturing plants to cattle farms. Modern M2M applications utilize electronics and wireless technology, with devices embedded in various machinery collecting and distributing real-time data. This method is expected to connect over 10,000 million industrial devices soon, creating a large-scale data storage network. Telecommunications and major technology companies (Microsoft, Google, Amazon) recognize the opportunities to expand services and access different aspects of customer operations. Therefore, the focus is shifting towards offering new services that emphasize data transmission over the Internet and data storage in cloud servers.

(2) Maintenance and upgrades

Maintenance that is predictable brings increased reliability and efficiency to various appliances, ranging from espresso machines to sensors in jet engines and turbines of IBM power plants. IBM is one of the companies benefiting from this development. Through artificial intelligence analysis, it helps service users make informed decisions about choosing suitable days and times for maintenance. An example of this predictive maintenance development is applied to industrial machinery, such as excavators in the mining industry, indicating a market worth 5 trillion dollars annually. The opportunity cost of downtime for machinery maintenance is a significant factor in such businesses.

For leading companies in the industry, like Thiess, which manufactures mining equipment with over 700 models, stopping one machine in a mine for one day results in an average opportunity cost of 1.8 million dollars. Currently, sensors send usage data for all types of machinery over the Internet to a central system. This allows the scheduling of machinery downtime for maintenance, reducing the losses incurred by opportunity costs when machinery in mines stops working. This new approach reduces losses due to downtime by up to 10%. Additionally, by connecting all data and processing information from Thiess' central system, a shift from traditional post-damage machine repair (Corrective Maintenance) to maintenance to prevent anticipated damage (Predictive Maintenance) has occurred, bringing substantial value to the mining industry.

(3) Engagement

By actively engaging and interacting with customers throughout the usage period, manufacturers and customers can share information through various household appliances, such as refrigerators, electric toothbrushes, televisions, and vacuum cleaners. The shared user data can add value to the products, leading to a shift from manufacturing-centric to service-centric business models, which often have higher value. Product or equipment development also contributes to enhancing users' capabilities, potentially leading to improved health or increased special skills, creating sustained benefits and adding value to the products or equipment. For example, optimizing the use of products to enhance their capabilities and improve predictive maintenance can result in significant benefits in industries like mining.

Furthermore, continuous service provision is crucial in creating added value and fostering long-term relationships between product brands and customers (customers' experience and engagement). This, in turn, can generate consistent revenue in the future. The McKinsey report (2018) summarizes technological changes, as shown in Figure 12.4, highlighting the potential for data integration to be applied in conjunction with various sensors attached to machinery for detection and data generation. This leads to data storage throughout the machinery's operation, enabling the application of data analysis, big data analytics, artificial intelligence, and data exchange with other manufacturers in the supply chain. This integration enhances overall supply chain efficiency.

The report also suggests that the Industry 4.0 model can be applied to various production activities, as depicted in Figure 12.5, which illustrates factory activities related to Industry 4.0 and related sub-activities. These activities are detailed in the circular list shown in Figure 12.6, providing a clear understanding of how Industry 4.0 concepts are implemented in production activities

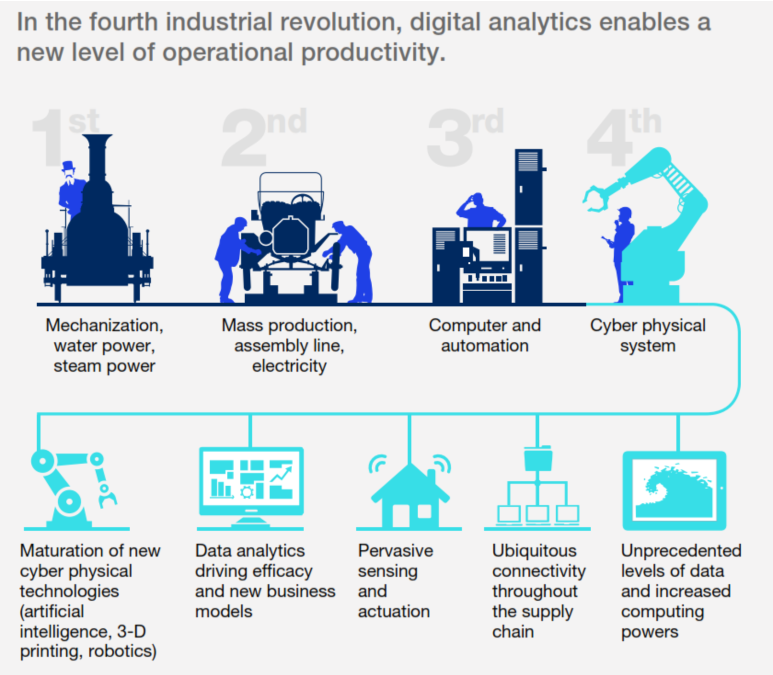

Figure 11.4: Industry Transformation Patterns from the Four Industrial Revolutions

Source: McKinsey (2018)

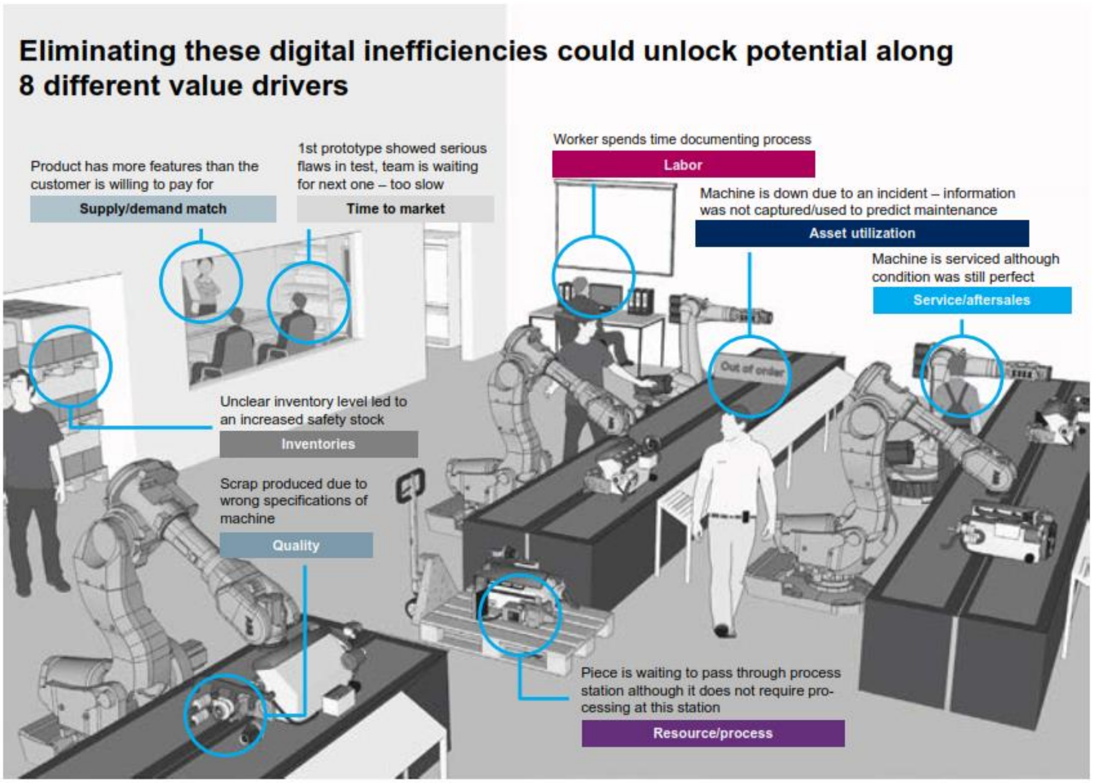

Figure 11.5: Examples of Application in Various Production Activities

Source: McKinsey (2015)

1 Maintenance, repair, and operations

Figure 11.6: Details of Applying Industry 4.0 for Improvements in Various Production Processes

Source: McKinsey (2015)

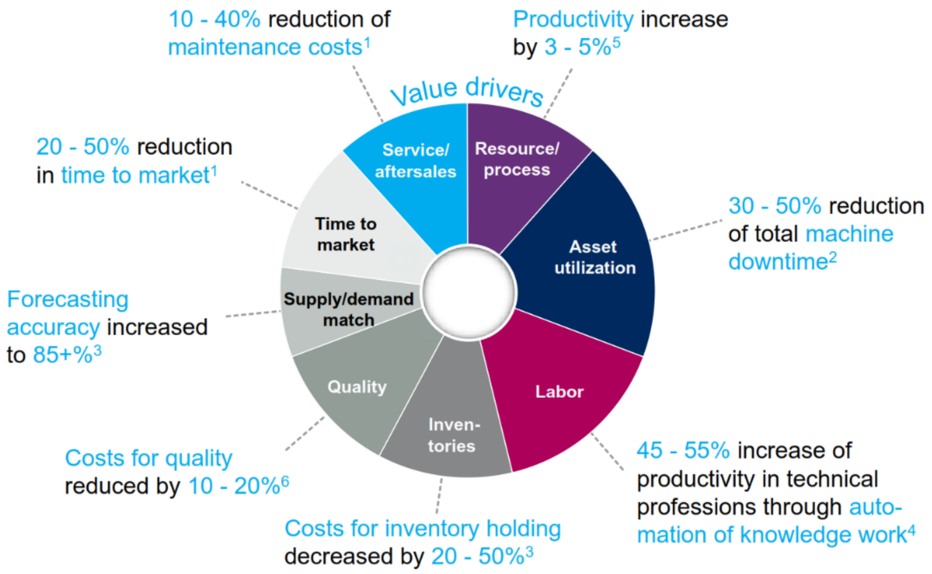

Figure 11.7 Estimated Financial Impact of Each Industry 4.0 Application Activity

Source: McKinsey (2015)

In addition to detailing the operations, the financial impact predictions are presented in Figure 12.7, reflecting the clear benefits of implementing Industry 4.0. This implementation can generate positive impacts on cost reduction, production efficiency improvement, and business forecasts.

Table 11.1: Ranking of Impacts Resulting from Various Activities in the Implementation of Industry 4.0

Activity	Benefits Resulting from Estimation
(1) Predictive and Preventive Capability	85%
(2) Increased Efficiency from Collaborative Work between Machinery and Production Specialists	45-55%
(3) Reduction in Machine Downtime	30-50%
(4) Time from Production to Market and Consumers	20-50%
(5) Cost Reduction in Product Storage	20-50%
(6) Decrease in Maintenance Expenses	10-40%
(7) Cost Reduction in Quality Control	10-20%
(8) Overall Efficiency Improvement	3-5%

Source: Compiled from McKinsey (2015)

Conclusion

This section has presented perspectives on future trends, indicating that manufacturing will undergo a transformation towards Industry 4.0. The main focus of this transformation is the integration through Cyber-Physical Systems (CPS), with key factors driving these changes including:

1. Easy and affordable internet connectivity, accessible everywhere.
2. Development of small, inexpensive sensors for physical data detection.
3. Low-cost large-scale data storage that can be stored in the cloud.
4. Efficient data processing, high-performance, and cloud-based.

This transformation has brought benefits to the industrial sector, including:

1. Machine-to-Machine communication, enabling automatic linking and processing between machinery.
2. Maintenance and upgrades that allow proactive forecasting, reducing financial losses from unexpected production halts.
3. Engagement, fostering consumer and other component manufacturer participation throughout the supply chain. This involvement can influence product characteristics from pre-production, or consumers and component manufacturers can participate in production monitoring, creating value from customer experience and engagement.

Therefore, the shift towards Industry 4.0 enhances manufacturing benefits by utilizing data and communication technologies. This leads to increased efficiency in industrial production. Moreover, it fosters collaboration between consumers and relevant component manufacturers, aligning activities in the service sector with manufacturing. The classification of economic activities into agriculture, industry, and services may need to be redefined in the future. This is because information technology, as presented, can be applied to enhance efficiency and value addition in both agricultural and industrial activities. This can contribute to elevating income levels, potentially shifting from the initial development sequence of decreasing agricultural activities in favor of industrialization. The use of industrial activities as a primary mechanism for income elevation may be reconsidered, given that information technology can be applied to enhance production efficiency and value addition in both agricultural and industrial activities. This, in turn, may contribute to increasing income levels for the labor force involved in agriculture and industry in the future.

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