History of the Industrial Revolutions

This article is part of the Digitalization Applications 101 learning module, which provides a comprehensive understanding on the basic concepts of digitalization terminologies, technologies and its applications in the steel industry. The course was developed by the Digitalization Applications Technology Committee as an introductory course to educate industry personnel in digitalization. Visit AIST.org/DT101 to view the full course materials.

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Revolutions in the past changed our world in dramatic fashion. America and Europe have both seen revolutions quickly change their societies, politics and sovereignty. The advancement in technology in the way people produce goods has been another revolution. The introduction of technology was to be a fundamental catalyst in the way people would produce goods for the next four centuries. While much slower paced than other social revolutions, the transformation of human society has been forever changed by the Industrial Revolution.

Definition

Prior to the late 18th century, all products and goods were produced by hand. Societies primarily focused on agriculture, with their respective economies based on farmland and producing crops. Eventually, these societies would see people move from the countryside to quickly growing population centers that focused on the mass production of goods in factories, resulting in dramatic cultural and historic changes across the world. This movement and its resulting advances in the way people produced things is commonly known as the Industrial Revolution.

History

First Era of the Industrial Revolution

— Beginning around 1760 in Great Britain, the transition from the agrarian society working crops in the fields to new manufacturing processes was greatly affected by the use of water and steam. Using sources of energy derived from steam and coal made the utilization of machines in manufacturing faster and more efficient. The textile, iron and transportation industries are three examples profoundly affected by this transformation by the early 19th century.

Second Era of the Industrial Revolution

— Beginning around 1840, the second era began to prevail in Great Britain, Germany and America, and is often referred to as the technological revolution. The introduction of innovations using electricity allowed for even greater production efficiencies utilizing more sophisticated machines.

Third Era of the Industrial Revolution

— Beginning in the 1960s, the third era began with the introduction of the first generation of computers. These early computers were often very large and labor-intensive but would eventually provide the basic structure for how manufacturing would evolve over the next 60 years. Further evolution of the internet, renewable energy and innovations on the assembly lines to automate human tasks accelerated manufacturing productivity and efficiencies.

Fourth Era of the Industrial Revolution

— Beginning in the 2010s, the fourth and current era is the age of intelligent systems and facilities that can run without human intervention. The ability for these machines to exchange information, trigger events and control other systems has made further innovations possible in automated manufacturing processes.

Technical advances such as artificial intelligence, cloud technologies, the Internet of Things (IoT)

and machine learning are all evolving and continue to accelerate the innovative processes across all manufacturing.

Technologies

Textile Inventions — Several new technologies would represent and accelerate the various eras of the Industrial Revolution. In the agrarian societies of Great Britain, much of the textile industry was a single person working at home producing a minimal amount of material each day, limited by the length of their outstretched arms due to how these looms were operated. Anything wider required multiple people, resulting in a process that was slow and inefficient.

In 1733, John Kay invented and patented the first automated flying shuttle, which greatly increased the speed of textile weaving. The invention's popularity led to a shortage of yarn and thread, creating opportunities for others to innovate other spinning machines.

James Hargreaves invented a machine in 1767 that would forever change the textile industry. The spinning jenny was created out of this shortage of materials to produce more yarn and thread. Over time, the design of the spinning jenny would be improved and eventually be too large to be used in homes. This led to the development of jenny shops, which marked the transformation from domestic spinning to mechanized spinning mills. The impetus of moving from home-based businesses to a factory system had begun.

In 1769, shortly after James Hargreaves invented the spinning jenny, another man developed his own version of a spinning machine operated by water power. The water frame produced a stronger weave of thread than the spinning jenny with less human labor and, eventually, numerous factories began operating with the water frame throughout England.

The further development of the factory system and the population movement from the countryside to urban areas led to people looking for jobs beyond farming. The necessity of weaving one's own clothes became less and less, leading to further innovations. In 1784, Edmund Cartwright developed the power loom out of the need to mechanize the weaving process. It tremendously sped up the process of weaving cloth while making unskilled labor less expensive at the same time.

Steam Power Inventions — One of the most significant innovations to drive the beginning of the Industrial Revolution was the first modern "atmospheric steam engine," or what we know today as the common steam engine, by the British engineer and inventor Thomas Newcomen in 1712.

While there had been previous versions of engines utilizing steam to create a vacuum, Newcomen's version was the first to use what is now known as "piston in the cylinder" approach. The evolutionary engines became extremely useful for removing water from mineshafts and raising water to power water wheels, which were used to supply much-needed power.

In the 1760s, building on Newcomen's atmospheric steam engine, a Scottish mechanical engineer began to improve on the design by increasing its efficiency and making it less expensive to run. James Watt would go on to determine that by using a separate chamber to condense steam, he would not need to cool the rest of the engine.

His innovations and improvements of the first atmospheric steam engine would propel the world even further into the Industrial Revolution as he would partner with a financial investor, Matthew Boulton, and form the Boulton & Watt Co. They would continue to make further improvements and patent other important inventions.

Usage of Raw Materials — Coal was by far the most common natural resource used to produce energy during the first era of the Industrial Revolution. It was able to produce higher amounts of heat and power early machines, which increased factory efficiencies and reduced needed labor. Coal was valuable and plentiful in supply.

A new method of smelting raw iron ore with coke allowed for less expensive production, resulting in materials that were higher quality than previous methods. This allowed the steel industry to expand by increasing demand and eventually contribute to the growth of the railroad industry.

Overall, the first age of the Industrial Revolution used large amounts of natural and non-renewable resources, which had many unintended consequences that would be not known for decades. However, as technology has vastly improved over time, the search and discovery of new and renewable resources greatly increased.

Silicon and Semi-Conductors — As we venture further into what is now Industry 4.0, we are seeing technologies work to improve existing and new production processes. Furthermore, the ability to use these technologies in our everyday lives will play a major contribution in connecting humans with IoT-enabled devices and sensors. Sensor-driven analytic platforms will make work and home spaces more energy efficient and control irrigation and water supplies. Transportation services will build upon previous-generation technologies and make them even more effective while costing less.

3D printing, artificial intelligence (AI), big data analytics, robotics, virtual and augmented reality

are all evolving technologies in the 21st century that will expand mass production and supply chains with digital transformation. This new era of the Industrial Revolution is causing rapid changes in the way companies deal with supply and demand and customer relationships, and will require industries to employ new disciplines to work in new ways to achieve the full benefits of transformation using these evolving technologies.

Example Applications

The technological advances made during the Industrial Revolution led to many new advances in several areas.

Advances in steam power and the inventions of steam and internal combustion engines led to many innovations in transportation.

For example, the steam-powered locomotive invented in 1804 in England by Richard Trevithick displayed the ability to transport 10 tons of iron for 10 miles. Some 20 years later, George Stephenson further developed the steam-powered engine, which led to greater efficiencies in design and the creation of rail links between coalfields and shipping ports.

On the water, steam-powered ships replaced sails and manually oared boats. The history of the steam ships mimics the steam locomotives. In 1807, Robert Fulton developed a steamboat for use on river systems in New York, N.Y., USA. After several years of attempts at steam-powered ships that were unsuccessful due to being too slow and underpowered, Fulton launched the Clermont, which could transport cargo and people up and downriver. A few years later in 1812, William Symington would demonstrate the first steam-powered passenger boat in Europe. Further innovations led to the steam turbine, which is a major component of electricity today.

No application or invention of the Industrial Revolution may have changed the future of the world more so than the invention of the automobile. While there were several attempts at creating automobiles powered by steam, electricity and gas during the 18th and 19th centuries, the invention of the Quadricycle in 1896 proved to be the game changer. It was this invention that eventually led to, after two prior failed attempts, the Model T and the creation of the Ford Motor Co. By utilizing efficient and repetitive manufacturing processes, including the assembly line, Ford was able to produce automobiles inexpensively and passed along a portion of the savings to the customers. This single innovation was a turning point in history.

Another important invention in the second era of the Industrial Revolution was the airplane. In a sand dune in North Carolina, two brothers and pioneers of early aviation, Wilbur and Orville Wright, were attempting to prove manned flight was possible by mimicking the wings of birds that used them for balance and control. By the addition of a motion control mechanism, they were able to successfully conduct the first free, controlled flight of a power-driven plane. Orville's inaugural flight only lasted for 12 seconds and about 120 feet; however, Wilbur's second attempt that day was an impressive 59 seconds and 852 feet. Their legacy would accelerate further flight technology, eventually resulting in the rapid development of military aircraft within a decade and landing a man on the moon within 70 years. The evolution of flight in that timespan was an incredible achievement.

In terms of applications of inventions and innovations in communication, the telegraph, telephone and radio stand out as tremendous innovations. The telegraph did not require line of sight to communicate with the recipient. Adding electricity to the design allowed for long-distance communication with the intended recipient. Telegraph lines and railroads were usually adjacent to each other, allowing the further development of railroad lines across the United States.

Following further development of the telegraph, Alexander Graham Bell experimented with using technology to carry human-made sounds across wires. The ability to communicate human sounds instantaneously to a recipient at a distant location would be a great achievement in the industrial age and was successful on 10 March 1876 when Bell would make the simple statement to his assistant, Thomas Watson, "Come here, I want to see you." Subsequent improvements have led to communication across even greater distances, including the first transcontinental call in 1915, and has proven to be one of the most significant inventions in the 19th and 20th centuries.

When radio arrived at the end of the 19th century, the thought of "wireless" communication over long distances did not seem plausible in a world dominated by the telegraph and telephone. Guglielmo Marconi proved otherwise by developing and demonstrating the first long-distance wireless telegraph and in 1901 broadcast the first transatlantic radio signal over the Atlantic Ocean. Telephones only allowed for one-to-one communication, whereas radios allowed communication to many recipients at one time. The ability to transmit news and information to the masses was essential during wartime and the evolution of the industrial age.

In the 21st century, technology will drive the fourth Industrial Revolution. Machine learning, AI and computational power will allow for the growth of "smart factories" where cyber-physical systems will control the areas of a production facility by making decisions based on learned data.

Such an idea will be possible on those and other growing technological concepts. AI will allow computers to "think" like people and make decisions based

on programmed methods and large amounts of data. 3D printing allows manufacturers to print their own parts, which significantly decreases potential costly downtime.

IoT will utilize sensors to better manage whatever it is they are using, whether it is for a "smart home," the car you drive, your "smart watch," security systems, or landscaping systems that will utilize sensors to know when a sprinkler system should turn on and off based on time but on moisture in the soil.

Summary

Whereas the first three eras of the Industrial Revolutions took several decades to complete, the fourth generation is in process. In the 21st century, the dawn of the fourth Industrial Revolution will continue to accelerate and impact people and societies throughout the world.

While the first era provided the world improved sources of energy and innovations to get out of the country and into population centers while providing mechanized ways to do what humans had been doing by hand for centuries, the second era built on that foundation by providing even more efficient energy sources and mass production capabilities. The third era gave us the electronic revolution, including modern electronics, computer systems and early automation capabilities.

The fourth era, known as Industry 4.0, will continue to build on the previous foundations especially the outcome of the third era, digital and electronic revolution.

Digitalization of supply and value chains, business models, and product or service offerings will continue to be emphasized and will lead to exponential change in the way we work and live as a global society. In fact, while it seems that this new era is just an extension of the digital revolution, it is moving so fast and creating such changes of great magnitude, it has been considered to indeed be the fourth and latest era of the Industrial Revolution.

There are several technologies pushing this age of innovation forward at lightning speed:

- New innovative materials.
- Internet of Things.
- Renewable energy sources.
- Artificial intelligence.
- Quantum computing technology.
- Augmented reality.
- Advanced robotics.
- 3D printing technologies.
- Big data.
- Smart sensors.

In conclusion, while the industrial age and its associated revolutions have provided staggering growth and advancement of our cultures and way of life in just a short 260 years, there have been many detriments as well. Pollution of land, air and water; poor and unsafe industrial working conditions; instances of child labor; elimination of labor due to increase in automation; greater segregation of classes in society between the wealthy and the workers; and elimination of small or cottage industries and companies that find it difficult to compete in the capitalistic economy with large-scale corporations are just some of those negative aspects of the industrial age.

However, the advantages of industrialization cannot be discounted. With the growth of various industries in all sectors of business, large-scale production of consumer goods is more accessible, higher quality and lower cost.

With the ability to increase and accelerate production, there is much competition, choice and opportunities for other factors to figure in the winners and losers in the marketplace. Business will be focused on customer service and fulfilling their expectations as "customer experience" will become a key performance factor in who dominates the product line.

Industries have accomplished this by saving time and labor while upgrading the skills of their employees, which usually means higher wages that lead to a better standard of living for families.

Due to this increasing standard of living, the poverty rate is much lower even though the disparity between unskilled labor and skilled labor continues to widen.

Finally, smart cars, drone technology and other advancements in transportation that are not possible yet will revolutionize transit, shipping and delivery systems. The world will truly become a much smaller place than it was as a farmer in the English countryside in 1760.

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