**Industrial Revolution 4.0:**

**Its Past, Present and Future**

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1. **Introduction:**

The world has witnessed remarkable periods of transformative change throughout history, marked by significant advancements in technology, industry, and society. The Industrial Revolution, a pivotal turning point in human civilization, has left an indelible impact on the way we live, work, and interact.

However, the story does not end there. As we stand at the dawn of the 21st century, we find ourselves amidst a new wave of profound transformation known as the Fourth Industrial Revolution, or Industry 4.0. This research explores the journey of Industry 4.0, its origins in the past, its current manifestations, and the exciting possibilities it holds for the future.

1. **Objectives of the Topic**

This specific research traverse between the topics concerning the Industrial Revolution of 4.0 and aims to explore the following:

* The past Industrial Revolutions that lead to the advent of Industrial Revolution 4.0
* The current state of the Industrial Revolution 4.0
* Technological Innovations of Industrial Revolution 4.0
* The impact of the technological innovations of Industrial Revolution 4.0 towards the environment and society,
* The future of the Industrial Revolution 4.0 and the possible Innovations of the forthcoming Industrial Revolution 5.0.

1. **Scope of the Topic**

This study only covers the technologies and Innovations within the ambit of the Industrial Revolution 4.0, as well as the following topics:

* The preceding Industrial Revolutions that lead to the I.R. 4.0
* The advantages and disadvantages of the I.R. 4.0
* Major technological advancements and innovations within I.R. 4.0
* The forthcoming of Industrial 5.0 and its possible technologies and innovations

1. **Presentation of the Topic**

**The Past**

In modern history, the Industrial Revolution was the transition from an agrarian and handicraft economy to one dominated by industry and machine production. These technological advancements provided new methods of working and living, drastically altering civilization. This procedure began in the 18th century in Britain and extended throughout the world from there.

The English economic historian Arnold Toynbee (1852-83) used the phrase "Industrial Revolution" to describe Britain's economic development from 1760 to 1840. Since Toynbee's time, the phrase has been used to refer to a process of economic transition rather than a period of time in a specific location.

**THE START OF INDUSTRIAL REVOLUTION?**

**First Industrial Revolution**

The Industrial Revolution, which occurred between 1760 and 1830, was centered in Britain. The British, well aware of their technological head start, banned the transfer of manufacturing technology, expertise, and equipment abroad. William and John Cockerill, two Englishmen, brought the Industrial Revolution to Belgium by establishing machine factories in Liège (about 1807). The iron, coal, and textile industries were at the center of the Belgian Industrial Revolution, as they were in Britain.

The creation of the stationary steam engine was a key component of the Industrial Revolution. However, most industrial power was provided by water and wind throughout the early phase of the Industrial Revolution. By 1800, steam was supplying an estimated 10,000 horsepower in the United Kingdom.

Thomas Savery invented the first commercially successful industrial application of steam power in 1698. Thomas Newcomen invented the first successful piston steam engine before 1712. Newcomen engines were mounted on the surface to drain previously unfeasible deep mines. Steam power transformed the first industrial revolution by providing a more efficient and flexible source of energy. Its use in industry and transportation enhanced productivity, enlarged markets, and advanced technology, setting the framework for future industrial revolutions and defining the contemporary world.

Overall, the First Industrial Revolution was an important period in human history, moving societies toward industrialization, urbanization, and technological advancement. Steam power transformed the first industrial revolution by providing a more efficient and flexible energy source. It had a huge impact on industry and transportation, increasing production, opening up new markets, and contribute to technological developments. The effect of steam power went beyond Britain, inspiring future industrial revolutions and leaving an indelible mark on the modern world.

**Second Industrial Revolution**

The time between the 1760s and about 1840 was the first Industrial Revolution. Here is where the second industrial revolution picked up. Despite significant overlap with the "old," there was rising evidence for a "new" Industrial Revolution in the late 19th and 20th centuries. Historians refer to this as "The Technological Revolution," which mostly occurred in the United Kingdom, Germany, and America. In terms of raw materials, contemporary industry began to make use of a wide variety of previously undiscovered natural and synthetic resources, including rare earths, new alloys, plastics, and other synthetic products. These, together with advancements in machinery, tools, and computers, gave rise to the automatic factory.

Although some parts of industry were almost entirely mechanized in the early to mid-19th century, automatic operation, in contrast to the assembly line, first achieved major significance in the second half of the 20th century. Assembly lines and the utilization of oil, gas, and electricity were introduced during the second industrial revolution. These new power sources, together with more improved communication methods such as the telephone and telegraph, enabled mass production and some degree of automation in manufacturing operations.

Technology like the telegraph was widely used because of improvements in manufacturing and industrial technology. In May 1837, Sir William Fothergill Cooke and Charles Wheatstone set up the first commercial telegraph line between Euston train station and Camden Town in London. Alexander Graham Bell got the first patent for the telephone in 1876.

With the phone and telegraph, people could talk to each other over long distances more quickly and more reliably. This made it easier for the different parts of the manufacturing process to work together and for suppliers, distributors, and buyers to talk to each other and the company. Sharing information at the right time made production planning, inventory management, and order processing more efficient.

Assembly line production was a big step forward in the late stages of the Second Industrial Revolution. It means that workers make a product or good by moving along a motorized or automated line. The product moves through the line, and each worker does a distinct task in order to make the product. The Ford Motor Company in 1913 was the most well-known company to use an assembly line. The car, which Henry Ford made, is one of the most important things to come out of the Second Industrial Revolution. To be clear, Henry Ford did not create the first automobile in history.

With assembly lines, new power sources, and better ways to talk to each other, manufacturing processes were able to become more automated. Automation is the use of machines and technology to do things that used to be done by hand. This saves time and makes things more efficient.

**Third Industrial Revolution**

People also call the third industrial revolution the "Digital Revolution" or the "First Computer Era." It started in the 1970s of the 20th century. During this time, relatively basic but comparatively large computers were developed. These computers were pretty good at what they did, and they helped pave the way for the machines we use today. Digital logic, MOSFETs (MOS transistors), integrated circuit (IC) chips, and the technologies that come from them, like computers, microprocessors, digital cell phones, and the Internet, are at the center of this transformation.

In 1947, the first working transistor, the germanium-based point-contact transistor, was invented by John Bardeen and Walter Houser Brattain while working under William Shockley at Bell Labs. It has been called the "most important invention of the 20th century." This led the way to more advanced digital computers.

John Bardeen, William Shockley, and Walter Brattain from Bell Laboratories and the first germanium point-contact transistor

The establishment of the Advanced Research Projects Agency Network (ARPANET), an early packet switching network and the first to implement the protocol suite TCP/IP, was one of the first triggers of the Third Industrial Revolution in 1969. It was the catalyst for the birth of the Internet and the subsequent information revolution. The Third Industrial Revolution (TIR), like earlier revolutions, is primarily driven by technology breakthroughs in manufacturing, distribution, and energy concerns. The Third Industrial Revolution also called The Digital Revolution is both global and local, giving rise to the term 'glocal'. The TIR will alter the way we work, produce, and entertain.

**The Present**

The Industrial Revolution 3.0 may have ended, but the end of this era prepared the stage for a greater advancement in technology and innovations that made the world interconnected and greatly improve our quality of life. This great leap of technological advancement is known as Industrial Revolution 4.0.

**The Industrial Revolution 4.0**

The Fourth Industrial Revolution, also known as Industry 4.0, is an era characterized by the fusion of advanced technologies that are reshaping industries and society at an unprecedented pace. There is no exact time or date that marked this era, but during the mid-2010 and early-2011 I.R. 4.0 opened it stages when the German Government conducted a project that aims for the digitization of the country’s manufacturing sector for better and more efficient work flow (Bloem et al., 2014).

This revolution is driven by transformative technologies such as artificial intelligence (AI), the Internet of Things (IoT), advanced robotics, big data, autonomous vehicles, cloud computing, big data, augmented/simulated reality, 3D printing, blockchain, nanomaterials, digital twins and automation (Rymarczyk, 2020). The Fourth Industrial Revolution holds immense potential for innovation, efficiency, and economic growth through improving an industry and solving problems that it currently faces (Harahap & Rafika, 2020). Despite the technological benefits that I.R. 4.0 offers, it also brings challenges that need to be addressed for a sustainable and inclusive future.

**Technological Advancements during I.R. 4.0**

The I.R. 4.0 utilizes the inventions of the third industrial revolution such as the computers, Internet and many more to create endless possibilities of technology (McKinsey & Company, 2022). According to McKinsey & Company (2022), the I.R. 4.0 brings us new technologies that can be classified into four categories, which are connectivity, data, and computational power, analytics and intelligence, human-machine interaction and lastly advanced engineering.

**Connectivity, Data and Computational Power:**

This categorization refers to the technological innovations that deals with Data and the use of IoT (Internet of Things) as a platform for unlimited connectivity wherever you are in the world (Gamil et al., 2020). Some of the technologies that is categorized under this classification are The Internet, Cloud Technology, Blockchain and Sensors.

**Analytics and Intelligence:**

Advanced Data Analytics, Artificial Intelligence and Machine Learning are some technologies that are being classified on this category. These technologies are grouped together due to the fact all of them processes gather and process data. These technologies rely on each other to enable the users of these technologies gather useful information from the data that they processed; these technologies are mainly applied in Data Science (Ongsulee, 2017).

**Human-Machine Interaction:**

The term "human-machine interaction" (HMI) describes how people engage and communicate with machines or computer systems. It includes all techniques, user interfaces, and technological advancements that make it possible for users to communicate and work effectively with machines. Intuitive and user-friendly interfaces that enable seamless communication and collaboration between humans and machines are the goal of HMI design (Johannsen, 2009).

Technologies such as virtual reality (VR) and augmented reality (AR), robotics and autonomous guided vehicles are just some of the technologies classified under this category (McKinsey & Company, 2022).

**Advanced Engineering:**

Advanced Engineering covers a lot of Engineering technologies such as Additive Manufacturing such as 3D Printing and Nanotechnology (McKinsey & Company, 2022). These technological innovations can be used in the world of engineering, for instance, 3D printing can be used for tissue engineering by enabling 3D cell culture within complex 3D biomimetic architectures (Zhu W. et al., 2016), while nanotechnology on the other hand can be used in the field of medicine, though it’s still on its very early stage yet it has promising potential benefits such as to cure cancer using nanotechnology (Nie S. et al., 2007).

**Industrial Revolution 4.0: Its Unintended Consequences**

Industry 4.0 have revolutionized the way we live, work, and connect with the world. With its promises of increased efficiency, connectivity, and automation, Industry 4.0 has undeniably ushered in a new era of progress and innovation. However, like a double-edged sword, this industrial revolution also carries with it unintended consequences that warrant careful consideration.

**Negative Impact on Employment**

The possible replacement of human labor by automation and artificial intelligence (AI) systems is one of the main issues raised by Industry 4.0. The job security of many people is under danger as a result of the increasingly capable capabilities of advanced robotics and AI algorithms. Millions of jobs across industries could be lost due to automation, which will increase unemployment and economic inequality (Smith, 2020).

**Erosion of Privacy and Data Security**

The expansion of data collecting and analysis brought on by Industry 4.0 has caused serious privacy and data security problems. Device connectivity and the Internet of Things (IoT) make it possible to continuously monitor and collect personal data, which may be a goldmine for businesses and governments. This vast data gathering may violate people's privacy, which raises moral dilemmas about consent and control over personal data (Johnson, 2019).

**Widening Social Inequality**

Even though Industry 4.0 promises to increase productivity and boost economic growth, it also makes social inequities more pronounced. Automation and cutting-edge technology tend to benefit a select few, expanding the gap between the wealthy and the marginalized. People lacking the appropriate skills and education face greater impediments to employment and economic mobility as sectors automate and low-skilled occupations are removed (Anderson, 2018).

**Negative Environmental Impacts**

**Increased Energy Consumption**

The growth of networked gadgets, data centers, and smart infrastructure that make up Industry 4.0 all demand significant energy inputs. This increase in energy demand exacerbates climate change by increasing greenhouse gas emissions. The energy requirements of Industry 4.0 technologies, such as AI algorithms and cloud computing, strain current power grids and increase dependency on fossil fuel-based energy sources, as pointed out by Thompson (2022).

Industry 4.0's rapid technological change causes a substantial amount of electronic garbage (or "e-waste") to be produced. Older devices are discarded, often carelessly, as newer, more sophisticated technology take the place of their predecessors. Hazardous substances included in e-waste, like lead, mercury, and cadmium, pose substantial risks to both human health and the environment. Johnson (2023) claims that poor recycling and disposal of e-waste from Industry 4.0 contaminate ecosystems, threaten wildlife and human populations, and cause soil and water pollution.

**Resource Depletion**

The extensive use of natural resources in the production and operation of Industry 4.0 technologies contributes to resource depletion. The extraction of rare earth minerals and other raw materials necessary for manufacturing high-tech devices has detrimental effects on ecosystems and biodiversity. Furthermore, the continuous demand for these resources drives unsustainable mining practices, as highlighted by Anderson (2021), leading to habitat destruction, deforestation, and loss of biodiversity.