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10 September 2021

Haradhan Kumar Mohajan: Journal of Social Sciences and Humanities,
Vol. 7, No. 4, 2021, pp. 239-251

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Abstract

During the first industrial revolution (IR1) human and animal labor technology converted into machinery, such as the steam engine, the spinning jenny, puddling and rolling processes for making iron, coke smelting, etc. During the second industrial revolution (IR2) electricity, internal combustion engine, indoor plumbing, chemical industries, etc. technologies are developed. The third industrial revolution (IR3) began in the 1950s that is considered as the move from mechanical and analogue electronic technology to digital electronics. Nano, bio, and IT technologies, 3D printing, artificial intelligence, robotics, etc. are the most important driver of the IR3. During the IR1&2s only Western Europe and the USA were developed but during the IR3 the world becomes about 10 times wealthier, and development spreads almost every part of the world. In the IR3 there have been developed thousands of businesses organizations and millions of jobs globally. Major modern inventions are happened in the IR3. Economic development, development of transportation, development of 3D printing, robotics technologies, fab lab, etc. are extraordinary activities during the IR3. In the IR3 standard of living and life expectancy of every nation has increased than that of the IR1&2s. The IR3 has also some negative impacts, such as air pollution, biodiversity reduction, water pollution, habitat destruction, greenhouse gas emissions, global warming and climate change, etc. This study has tried to discuss various aspects of IR3 in some details.

Haradhan Kumar Mohajan: Journal of Social Sciences and Humanities,
Vol. 7, No. 4, 2021, pp. 239-251

Keywords: Digital Revolution, 3D Printing, Economic Development, Industrial Revolution, Renewable Energy, Robotics

1. Introduction

Before the first industrial revolution (IR1) about 60% of global wealth and power were in the two Asian countries: China (33%) and India (25%). On the other hand, combine about 2% global wealth and power were in the two countries: the UK (1.9%) and the USA (0.1%) [9, 28]. Then living standards were minimal and everyone in the society was poor. Most people worked from sunrise to sunset for managing adequate food, shelter, and clothing mere for survival. The child mortality rate was very high and life expectancy was very short, about 25 years [30].

The IR1 (1750-1840) began in Britain in the late 18th century that mechanized many previously manual tasks [4]. The steam engine and textile industry were invented at that time, which created a new productive age based on the concept of mechanization, centralized factories, and industrial capitalists [81, 90]. After the IR1 (1880) about 40% of global wealth and power were shifted in two countries of the west: the UK (23%) and the USA (15%), and about 15% was in two countries of the east in China (12.5%) and India (2.8%) [28, 113]. Although the IR1 increased the quality of life in many sectors, but it increased discrimination in the society and the outbreak of disease, due to an inability to meet rapid urbanization and fail to develop the health sector in parallel [100].

The second industrial revolution (IR2) (1860-1914) began at the early 20th century that brought standardization and mass production [40]. During the IR2 Henry Ford propelled the moving assembly line and enormous production has commenced. Railways and iron steamship, telephone, internal combustion engine, electricity, electric light bulb, automobile, the radio, airplane, and computer were invented in the IR2. During the IR1&2s there were lower prices but higher quality products [82, 125]. English mathematician, Charles Babbage, invented the automatic digital computer during the mid-1830s. At the start, computers shared with the steam engine, the internal combustion engine, and the electric motor for the many-faceted benefits of replacing human effort, less boring, making jobs stress-free, and

less monotonous [123].

The Third Industrial Revolution (IR3) began in the 1950s and reached its peak in the dot.com era of the late 1990s, and it continues at present, 2021. It is expected that IR3 will end around 2030s. The IR3 is considered as the movement from mechanical and analogue electronic technology to digital electronics, such as green buildings, electric cars, and distributed manufacturing. It is based on energy transition and digital technologies, and the internet, and called "*The Digital Revolution*" [18]. Recent world has been moving from information society to knowledge society and also to ubiquitous knowledge society. The IR3 emerges from the corporate industry's opportunity that brings on by nanotechnology, intelligent systems, 3D printing and robotics for industrial production and domestic services. In the center of IR3 there are two technologies; the microelectronics and the internet [5, 125]. In the IR3, the combination of digital manufacturing and personal manufacturing began that enhanced the smoothness in the global economy [129]. The IR3 is built upon a foundation of increased energy efficiency. Modern computer, lean production, internet, and biotechnology were invented in the 1970s [125].

In the IR3, great inventions were semiconductors, mainframe computer, microprocessors, MOS transistors, worldwide web, internet (an ultra-fast 5G communication internet, a renewable energy internet, and a driverless mobility internet), renewable electricity, e-commerce around 1995, and later developed Smartphone [41]. The IR3 develops from the corporate industry's opportunity to benefit from the forthcoming trends [99]. In the IR3 global wealth and powers again moved to the east. In 2010, only China captured about 20% of the global manufacturing output, and about double of the US global production market [138]. It is believe that nano, bio, and IT technologies, 3D printing, artificial intelligence, robotics, etc., are the most important drivers of the IR3. The IR3 has highly influenced in the various modern sectors, such as advanced manufacturing, education, information and communication technologies (ICT), defense, health, education, financial, and administrative sectors [100].

It is an era of rapid technological progress associated with the development of ICT. The IR1&2s improved only Western Europe and the USA, i.e., the development became local. But the IR3 the development became both local and global, and the world becomes about 10 times wealthier during the IR3. It creates thousands of business organizations, and millions

of jobs and ushers [116]. American economist and social theorist, Jeremy Rifkin (1945-), has operated with energy matters since 1973. He has aided the EU to design a road map for the future, called Digital Europe, and was the main architect behind China's information superhighway, called China Internet Plus [98].

2. Literature Review

Josef Taalbi inspects the factors that shaped the long-term evolution of the ICT industry during the IR3 in Sweden. His study supports some formalized facts about technological interdependencies in common-purpose technologies; a closely knitted set of industries has provided positive and negative driving forces for the development of ICT innovations [125]. Gerard Rijk and Marco Gulpers observe that the IR3 will on the one hand save the earth and, on the other, accommodate the consumer explosion that expect in the coming periods. During the IR3, the world is currently facing some interdependent crises, such as demographic outburst and fast consumer growth; current value and ethics, and necessary changes; financial, economic and social crises; climate, water, and energy crises; food scarcity, the change in global money streams, and political instability [99]. Brian H Roberts has observed that during IR3 significant changes have happened almost every feature of our society, especially in the way we live and plan, such as in belief, social classifying, manufacturing and distribution, international dealings, trade relations, and technological advancements [100].

Stephanie Ishack and Shari R. Lipner showed that various materials that are essential and used for the treatment of COVID-19, such as N95 respirators masks, surgical face shields, ventilator valves, shells of handheld body temperature monitors, and medical goggles are made very quickly by using 3D-printed technology [56]. C. Andrew Keisner and his coauthors have discussed the robotics technology innovation. They have indicated that robot use is mainly located in the USA, Europe, but recently the technology is increasingly in Japan, the Republic of Korea and China [63]. Jari Kaivo-oja and his coworkers have presented a roadmap of robotics, such as crucial characteristics of industrial and service robotics, and discuss technology foresight insights and inter-linkages to robotics. They further have shown key challenges of future work life and labor policy in economic, social,

and political areas of the EU [58].

Joseph Connors and his coauthors have discussed the global economic situation from 1800 to 2020. They indicate that during the IRs economic development became enormously; transportation in road, air and water become revolutionary; technology has changed dramatically. Transportation and delivery costs in every sector have reduced. Increase of per capita GDP in developed and developing countries are indicated with statistical data [30]. Jeremy Rifkin indicates that in future common people can be able to produce their own usable renewable energy in their homes, offices, and factories; and share this green electricity with each other [98].

3. Methodology of the Study

Before industrial revolution and during the three industrial revolutions global wealth moves in different parts of the world. The steam engine and textile industry were invented during the IR1. In the IR2, railways and iron steamship, electricity, electric light bulb, telephone, internal combustion engine, automobile, radio, airplane, computer, etc. were invented. On the other hand, there happens "*The Digital Revolution*" in the IR3.

For the proper academic development contribution in research is essential. Research methodology provides a fruitful research to a researcher. This article is prepared on the basis of historical research. Secondary data is used to ornament this article. The data are collected from books and e-books of famous authors, published and unpublished articles, various theses, research reports, etc.

We have divided the IR3 into four periodic intervals and have arranged the inventions and historical events accordingly. Then we have highlighted various developments that happened during the IR3. Later, we have tried to discuss the five energy pillars. Many crises arise in the IR3 and we have discussed them briefly. Finally, we have enlightened both positive and negative effects of the IR3.

4. Objective of the Study

Main objective of this study is to discuss the aspects of IR3 in some details. Other some minor objectives are to;

1) highlight various developments in the IR3,

2) indicate five pillars of the IR3,

3) specify the crises in the IR3, and

4) show the negative effects of the IR3.

5. Periodic Intervals during the IR3 (1950-2013)

There was an enormous development of the world during the IR3. It has created thousands of business organizations and millions of jobs globally. There were many new inventions and many historical events happened during the IR3. The total IR3 period is divided into four periodic intervals as follows:

5.1. Start of IR3: 1950-1969

In 1950, American mathematician and computer scientist, Richard Hamming (1915-1998), invented Hamming codes at Bell Labs, which was important in coding theory [34]; American electrical engineer Hubert Schlafly (1919-2011) invented the teleprompter camera [23]; the first credit card (Diners Club) was invented by Frank McNamara, Ralph Schneider and Matty Simmons [117]. Korean War (1950-1953) was a battle between the Democratic People's Republic of Korea (North Korea) and the Republic of Korea (South Korea) in which at least 2.5 million peoples had died and most of them were innocent. In that war, the USA supported South Korea, while China supported North Korea [105]. In 1951, American chemist Harry Wesley Coover Jr. (1917-2011) invented super glue; the first video tape recorder (VTR) was invented by American engineer Charles Ginsburg (1920-1992) [57]; power steering in motor car was invented by engineer Francis W. Davis [109]; the first heart-lung machine that allows advanced life-support during open-heart

surgery was invented [49]. In 1951, famous physicist Albert Einstein warned all the nations that nuclear war would lead to mutual destruction [16]. In 1952, the first patent for bar codes was invented by two American inventors Joseph Woodland (1921-2012) and Bernard Silver (1924-1963) [111]; the evolution of digital design and Computer Numerical Controlled (CNC) machines introduced to the market [73]; the first effective *polio vaccine* was advanced by American physician Jonas Salk (1914-1995) [17]; the hydrogen bomb was invented by Edward Teller's team of the USA [15].

In 1953, the double helix, the twisted-ladder structure of deoxyribonucleic acid (DNA) was discovered by American molecular biologist, geneticist and zoologist, James Watson (1928-) and British molecular biologist, biophysicist, and neuroscientist Francis Crick (1916-2004) that was great invention in modern molecular biology [135]; the invention of Black Box was a highly valuable that was used to record flight data and events [91]. In 1954, Solar Battery was invented by Bell Telephone scientists, Calvin Souther Fuller, Daryl Chapin and Gerald Pearson capturing the sun's power that collects energy from the sun and turns it into a current of electricity [26]. The first successful kidney transplant is performed by Joeseph E. Murray and his colleagues at Peter Bent Brigham Hospital in Boston [46]. Transistor Radio from Texas Instruments is a small *portable radio* receiver that used four-transistor-based circuitry [71]. The 1954-1968 civil rights movement, mass protest movement against racial segregation and discrimination had revealed in the southern USA [76].

In 1955, Tetracycline was invented that is active against a wide range of microorganisms [89]. Optic fiber was invented by Indian-American physicist Narinder Singh Kapany (1926-2020) [12]. The Vietnam War, also known as, the Second Indochina War; was a conflict in Vietnam, Laos, and Cambodia from 1 November 1955 to the fall of Saigon on 30 April 1975 [84]. In 1956, the Hard Disk Drive was invented by IBM [1]; the Southdale Shopping Center, the world's first enclosed; climate-controlled shopping mall was opened in the USA [95]. The Hungarian Revolution of 1956 was a nationwide revolution against the Hungarian People's Republic and its Soviet-imposed policies [70]. In 1957, the first personal computer, IBM 610, used by one person and controlled by a keyboard, was invented by International Business Machines Corporation (IBM) [114]; the gamma or scintillation camera, a device used to image gamma radiation emitting radioisotopes, was invented by American electrical engineer and biophysicist, Hal Oscar Anger (1920-2005)

[7]; the first artificial satellite, Sputnik 1, was built and launched by the Soviet Union [65].

In 1958, American electrical engineer Jack St. Clair Kilby (1923-2005) and American physicist Robert Norton Noyce (1927-1990) invented the integrated circuit [50]; the computer Bell 101 modem was invented by AT&T Corporation [14]; American physicist Gordon Gould (1920-2005) invented the laser that is used in industry, commerce, and medical treatment [22]. In 1959, the MOSFET (MOS transistor) was invented by the Egyptian-American engineer, physical chemist, cryptographer, inventor and entrepreneur Mohamed Atalla (1924-2009) and the Korean-American electrical engineer and inventor, Dawon Kahng (1931-1992) at Bell Labs [8]; the internal pacemaker was invented by the American engineer Wilson Greatbatch (1919-2011) [147]; Jack St. Clair Kilby and Robert Norton Noyce invented the microchip that changed the world [50]. Alaska was a Russian colony since 1744 until the USA bought it in 1867 for $7.2 million. In 1959, it became the 49th state of the USA. On the other hand, Hawaii was a kingdom until 1893 and became a republic in 1894. It then ceded itself to the USA in 1898 and became the 50th state in 1959 [36].

The Organization of the Petroleum Exporting Countries (OPEC) was established in Baghdad, Iraq, with the signing of an agreement in September 1960 by five countries; Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela [60]. In 1960, telephone companies began creating telephone bills from stacks of punch cards. During the 1960s the CNC entered the aircraft, shipbuilding and automotive industries [78]. In 1960, Theodore H. Maiman (1927-2007), a physicist at Hughes Research Laboratories constructed the first laser using a cylinder of synthetic ruby [47]. TIROS-1, the first weather satellite, was launched by the USA in 1960 [6]. In 1961, two Americans, physicist Robert Noyce (1927-1990), and electrical engineer Jack St. Clair Kilby developed the first prototypes of integrated circuits; the first industrial robot was invented by American inventor, George Charles Devol Jr. (1912-2011) and American physicist, engineer and entrepreneur Joseph Frederick Engelberger (1925-2015) in 1956, and was introduced by General Motors in 1961 [21]. In 1961, Russians send the first man, Yuri Gagarin (1934-1968), into space and one month later, Alan Shepard (1923-1998) becomes the first American astronaut in space [141]. In 1961, construction on the Berlin Wall the Communist government of the German Democratic Republic (East Germany) began to build a barbed wire and concrete that physically and ideologically divided Berlin from 1961 to 1989 [126].

During the Cuban Missile Crisis, leaders of the USA and the Soviet Union involved in a tense, 13-day political and military standoff in October 1962 over the installation of nuclear-armed Soviet missiles on Cuba. The USA and USSR came close to launching nuclear attacks [124]. In 1963, British accountant Edward Craven Walker (1918-2000) invented the Lava Lamp [43]. In 1963, the US President John F. Kennedy was assassinated by Lee Harvey Oswald [39]. In 1964, the computer coding language BASIC (Beginner's All-Purpose Symbolic Instruction Code) was introduced that was designed by John G. Kemeny and Thomas E. Kurtz [64]. In 1965, G. D. Searle & Company chemist James M. Schlatter created aspartame while synthesizing ingredients for a planned anti-ulcer drug [144]. In 1965, Soviet cosmonaut Aleksei Leonov (1934-2019) became the first person to perform a spacewalk exiting the capsule during the Voskhod 2 mission for 12 minutes and 9 seconds [108]. In 1966, the Soviet Union's Luna 9 was the first spacecraft landed on the Moon [33]. All cigarette packets in the USA must carry the health warning "*Caution! Cigarette smoking may be hazardous to your health*" [48]. In 1968, Civil Rights leader Martin Luther King Jr. (1929-1968), was assassinated in April by James Earl Ray [11]. Bank statements and insurance policies were soon computer printed; my personal American Express card was still stamped in 1968 [75]. In 1969, Neil Armstrong and Edwin E. Aldrin became the first men to arrive on the Moon during NASA's Apollo 11 mission [45]. The Advanced Research Projects Agency Network (ARPANET) was the first wide-area packet-switched network. It was established by the Advanced Research Projects Agency (ARPA) of the US Department of Defense. In 1969, it relayed its first communications between UCLA and Stanford [103].

5.2. Period: 1970-1989 of IR3

By the 1970s, even before the personal computer, monotonous retyping had been made obsolete by memory typewriters. Airline reservations systems came in the 1970s and by 1980 barcode scanners and cash machines were spreading through the retail and banking industries. Old-fashioned mechanical calculators were quickly rejected as electronic calculators, both miniature and desktop, were introduced around 1970 [96]. In 1970, the first jumbo-jet, the Boeing 747, entered the service and made its debut commercial flight from New York to London [55]. Computer floppy disks, a type of disk storage composed of a thin and flexible disk of a magnetic storage medium in a square, were introduced [140]. In 1971,

the first microprocessor, the 4004, was launched by Intel and VCRs were introduced [66]. In 1971, the Watergate Scandal began. It was a major political scandal in the USA involving the administration of US President Richard Nixon from 1972 to 1974 that led to Nixon's resignation [52].

In 1973, Skylab, America's first space station was launched. It was operated by three separate three-astronaut crews: Skylab 2, Skylab 3, and Skylab 4 [13]. The Vietnam War ends on 30 April 1975 [84]. On 4 April 1975, Bill Gates and Paul Allen created Microsoft that makes computer software [44]. On 1 April 1976, Steve Jobs and Steve Wozniak created the Apple Computer Company [68]. In 1977, Magnetic Resonance Imaging (MRI) scanner, a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body was first tested [85]. On 25 July 1978, Louise Brown, the very first test tube baby, who was conceived through in vitro fertilization (IVF), was born at Oldham and District General Hospital in Manchester, England [24]. The first personal computers arrived in the early 1980s with their word processing, word wrap, and spreadsheets. "Moore's Law" proceeded apace and allowed larger document and spreadsheet files to be handled faster. The multiplying power of computer chips was matched by increasing complexity of software, leading to the light-hearted verdict [140]. In 1980, 66 countries led by the USA boycotted the 1980 Olympics in Moscow because of the Soviet-Afghan War [32]. In 1980, the AIDS virus was identified by the US scientists, and in 1984 researchers finally identified the cause of AIDS [139].

The Sony CDP-101, released in 1982, was the world's first commercially released compact disc player [54]. In 1982, Sally Ride (1951-2012) became the first American woman in space [115]. Prime Minister of India, Indira Gandhi, was assassinated on 31 October 1984 at her residence in Safdarjung Road, New Delhi by her body guards Satwant Singh and Beabt Singh [74]. The 1984 Olympic was boycotted by a total of 14 eastern bloc countries, including the Soviet Union and East Germany, in reaction to the boycott of 1980 Moscow [32]. In 1986, Mad Cow Disease was a fatal disease that slowly destroys the brain and spinal cord in cattle was identified in Britain for the first time [59]. The Chernobyl nuclear reactor consists of four RBMK-1000 reactors, each capable of producing 1,000 megawatts (MW) of electric power, exploded in the USSR in 1986 [93]. The Iran-Iraq war (September 22, 1980-August 20, 1988) ended [101]. In 1989, the Berlin Wall was fall down at the end of the

Cold War [107].

5.3. Period: 1990-2005 of IR3

There was a burst of investment in the late 1990s as every large and small corporation developed its own web site; while many "dot.com" start-ups succumbed to overly optimistic plans, others like Amazon and Google developed commercial models that rose to dominance in the years after the dot.com stock market bubble peaked in early 2000. In the 1990s architects started using diffused computer-aided design (CAD) software [122]. In 1990, East and West Germany are reunited after the collapse of the Soviet Union [130]. In 1993, the North American Free Trade Agreement (NAFTA) was implemented in 1994 to encourage trade between the USA, Mexico, and Canada [132]. In 1993, Intel introduced the Pentium, a brand used for a series of x86 architecture-compatible microprocessor [3]. On 10 May 1994, Nelson Mandela became President of South Africa after being elected in the country's first multi-racial elections [86]. In 1995, the online auction website eBay was founded [119]. On 3 June 1996, the internet search engine "Ask Jeeves" was founded in 1996 by Garrett Gruener and David Warthen [120]. In 1998, the search engine Google was founded [104].

On 11 September 2001 (known as 9/11), 19 hijackers simultaneously took control of four US domestic commercial airliners. The hijackers crashed two planes into the World Trade Center in Manhattan, New York and within two hours, both towers collapsed. The hijackers also crashed the 3rd aircraft into the US Department of Defense headquarters, the Pentagon, in Arlington County, Virginia. The 4th plane crashed into a rural field in Somerset County, Pennsylvania [53]. In 2002, George Bush created the Department of Homeland Security on June 7th to fight threats of terrorism [146]. Facebook was launched as a social networking site only open to students from Harvard in 4 February 2004, by Mark Zuckerberg with his college roommates and fellow students Eduardo Saverin, Dustin Moskovitz, and Chris Hughes [88]. In 2005, the video-sharing website "YouTube" was founded by Steve Chen, Chad Hurley, and Jawed Karim in February 2005 [136].

5.4. Period: 2006-2030 of IR3

Apple introduced the iPhone on 29 June 2007 [77]. On 25 June 2009, American singer Michael Jackson (1958-2009) died of acute propofol and benzodiazepine intoxication at his home on North Carolwood Drive in the Holmby Hills neighborhood of Los Angeles. He was singer (King of pop), songwriter, and dancer (moonwalk) [67]. The first smartphone with a finger reader was the Motorola Atrix 4G in 2011. In 2019, the majority of smartphones released that had more than one camera, were waterproof with IP67 and IP68 ratings, and unlocked using facial recognition or fingerprint scanners [62].

6. Various Developments during IR3

Information Technology (IT) innovations, such as the internet, social media, mobile phones and apps, cloud computing, big data, e-commerce, etc. advanced the world in production, services, and business processes. Latest inventions, such as smartdust, quantum computing, brain-computer interfaces, autonomous vehicles, and 3D printing have made the life more comfortable [18]. Economic development, development of transportation, development of 3D printing, robotics technologies, fab lab, etc. are remarkable advances in IR3.

6.1. Economic Development

For more equitable and sustainable future, and survival of the life cycle in this green world we need a new economic structure [97]. There is an enormous economic development in IR3, such as international trade has extended, economic institutions have widen, entrepreneurial activities has increased, the living standards of people has increased, and life expectancy has increased in every nation. During IR3 a new global economy is established based on computers, the internet, telecommunications, and entertainment. Smart digital infrastructure is giving rise to a radical new sharing economy. The IR3 will spawn the new businesses and employment opportunities of a sustainable 21st century. Big Data and analytics are used to develop algorithms that increase productivity and reduce the production cost and services [30]. The per capita GDP of developed countries has increased

from $11,782 in 1960 to $44,514 in 2015. The corresponding figures of Sub-Saharan African countries are $1,935 and $3,466 respectively; and the corresponding figures of other developing non-African countries of the world are $1,698 and $11,015 respectively [19].

6.2. Development of Transportation

The invention of the Boeing 707 in 1958 had increased speed in airplane [38]. Transportation and communication costs have reduced in IR3. Addition of jet engine significantly reduced the cost of both air travel and shipment of cargo [30]. During IR3, the cost of air passenger transport has declined sharply. About 524 million people traveled from one country to another in 1995, but that figure expanded to 1.3 billion in 2017 [137]. Ocean shipping costs declined by more than 50% during 1974-2016 and air transport cost has reduced 78% during 1970-2019 [131]. The transportation and communication costs have reduced significantly during IR3, more production happened with lower costs. Advanced technologies and successful business practices are applied in economic activities. As a result, producers gained higher income, consequently became higher economic growth globally [19].

6.3. Development of 3D Printing

3D printing or additive manufacturing has been defined as the "*Process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies*." The 3D printing production process is organized completely differently from the manufacturing process of the IR1 and IR2 [10]. American inventor Charles (Chuck) W. Hull (12 May 1939-) is typically credited with the invention of the 3D printer via his Stereolithography Apparatus (SLA), patented in 1984. It can print shoes, clothes, car parts, toys, guns, artificial human body, etc. [51]. Recently, it can produce artificial heart pump, cornea, PGA rocket engine, jewelry collections, etc. [112].

It makes the prototyping process 10 times faster and 5 times cheaper than the normal R&D processes. Every nation producers can use 3D printers to create their prototypes in a matter of hours, instead of wasting months of time and potentially millions of dollars in R&D [118].

It is used in a wide variety of manufacturing, such as aerospace (e.g., turbine blades, fuel nozzles, structural members, etc.), medicine (e.g., implants, instruments, prostheses, etc.), defense (e.g., field replacement parts, inventory reduction, etc.), custom manufacturing (e.g., razor handles, sneaker soles, etc.), prototyping (e.g., structural electronics, fit/function validation, etc.), art (e.g., jewelry, costume design, footwear), hobbies (e.g., geometric designs, figurines, toys, etc.), and education (e.g., conceptual modeling, problem-solving, career readiness, etc.) [106].

There are different types of 3D printing depending on the size, detail and scope of a project, such as Fused Deposition Modeling (FDM), Stereolithography (SLA) Technology, Digital Light Processing (DLP), Continuous Liquid Interface Production (CLIP), etc. Recently, 3D printers became cheaper and all nations can use them for their necessary productions. The 3D printing market is growing at more than 100% per annum [121]. In general, it has five common parts: input material, print head, build plate, axes, and 3D design file [106]. The Economists have addressed 3D printing as the foundation of the IR4. The 3D printing revolution is happened from the top down to the bottom up in trade and consumption patterns [25].

The 3D printer has a variety of processes in which material is deposited, joined or solidified by computer-aided design (CAD) to create 3-dimensional objects by fusing 2-dimensional layers of cured photopolymers, extruded thermoplastics, welded metals, or fused powders [127]. The 3D printing allows products to be customized according to an individual's needs and preferences. It is used in several industries, such as automotive, aerospace, plastics, and medical. In the US industry two-thirds of manufacturers use 3D printing [92].

EADS, GE, Boeing, and Ford are using high-end 3D printing machines to produce critical parts for airplanes, automobiles, wind turbines, and a myriad of other machines [69]. In 3D printing the additive manufacturing process uses only the fixed amount of material needed to produce a product; while subtractive manufacturing processes remove materials to produce a product and generates waste that can be recycled into new stock [106].

During the COVID-19 pandemic, extreme shortage of personal protective equipment (PPE) and medical supplies, such as face masks, testing kits, nasopharyngeal swabs, and medical ventilators that leads to the collapse of total medical systems. Various companies and

individuals around the world used 3D printing to make medical goggles, face masks, nasopharyngeal swabs, valves for medical ventilators, shells of handheld body temperature monitors, and breathing masks [56].

6.4. Robotics Technologies

The term "robot" refers to forced labor. A robot is an electromechanical machine that has intelligent to do stipulate action guided by a computer program or electronic circuitry. It can perform tasks by moving into the real world. Numerous high-technology and artificial intelligence, such as information-, nano-, bio-technologies, are used to develop robots [20]. The word "robot" comes from the 1920s by Czech poet, Karel Capek, in a tragic play, *Rossum's Universal Robots*. The first industrial robot was developed in 1937 in the form of a small crane [42]. The reality of industrial robots came in the 1960s when Joseph F. Engelberger, the "*Father of Robotics*", introduced the Programmable Universal Manipulator Arm (PUMA) robot, weighed two tons, as a freely programmable, universal, and handling device [110]. According to the International Federation of Robotics (IFR), "*Robot is an actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks*" [63]. A robot with a cooperative behavior with the human when it is used; recently the fine term "cobot" has been given [2].

The word "Robotics" is an interdisciplinary branch of engineering and all branches of science. It is considered as the design, construction, implementation and operation of robots [142]. Recently, this branch has been spreading by the use of artificial intelligence devices in the manufacturing units [72]. Isaac Asimov coined and popularized the term robotics through many science-fiction novels and short stories. He invented the three laws of robotics as; i) a robot may not harm a human, ii) it must obey the orders given by human beings where such orders would conflict with the First Law, and ii) it must protect its own existence as long as it does not conflict with the operation of First or Second Law [102].

The development of global robotics strategy and artificial intelligence (AI) has taken special attention to human welfare, health, and safety issues [58]. Technological improvements in robotics and automation dramatically change in boost productivity and efficiency. Man-made robots have recently been trialed in supermarkets, schools, hospitals and some

other activities in Japan, Germany, the USA, and China. It is skills-biased and labor-saving. A robot sale was growing by 43% in both the USA and the EU in 2011 [63].

Robots can be used in the works that are dangerous, dirty, and/or dull (3D) for a human to perform, such as nuclear power plant, bomb disposal, risky space and undersea activities, toilet washing, municipal waste cleaning, etc. These can be used to collect information that is beyond 5 human senses, such as ability to see in the dark, detect tiny amounts of invisible radiation, measure movement that is too small or fast for the human eye to see [87].

6.5. Fab Lab

A fab lab or fabrication laboratory is a small-scale workshop that provides personal digital fabrication and also a global network of local labs [37]. The fab lab program began in 2001 as collaboration between the Grassroots Invention Group and the Centre for Bits and Atoms at the Media Lab in the MIT with a grant from the National Science Foundation of Washington, DC. It works to do almost everything for mass production [128]. It is linking to a global community of learners, educators, technologists, researchers, makers, and innovators. It consists of 3D printer of plastic parts, 3- axes CNC machines, printed circuit broad milling, microprocessor and digital electronics design, cutters for sheet materials. As of November 2019, there existed in total 1830 Fab Labs in the world and spans in all continents [134].

7. Five Pillars of the IR3

In the early 2015, Jean-Claude Juncker, President of the EC, arranged out his pathways for an “Energy Union” that downs energy prices, and reduces greenhouse gas (GHG) emissions. Solar power has been driven mainly by Germany and then in China. It is established on the basis of the three objectives of EU climate and energy policy: i) security of supply, ii) sustainability, and iii) competitiveness. The EU has targeted about 20% of renewable energy within 2020 [145]. The five energy pillars of the IR3 are [98]; 1) ever-changing to renewable energy, 2) altering the building stock of every continent into micro-power plants to collect

renewable energies onsite, 3) deploying hydrogen and other storage technologies in every building and throughout the infrastructure to store alternating energies, 4) using internet technology to change the power grid of every continent into an energy internet that acts just like the internet, and 5) transitioning the transport fleet to electric plugin and fuel cell vehicles that can buy and sell green electricity on a smart, continental, communicating power grid. These five-pillars will contribute the nations of the world off oil dependence.

Pillar 1: Renewable forms of energy are; solar, wind, hydro, geothermal, ocean waves and tides, and biomass (garbage, agricultural and forestry waste). At present these energies are very small percentage as compared to the global energy demand. Every nation should take attempts to produce energy from these renewable energy sources to create total green environment [98, 133].

Pillar 2: The countries which have enough sunlight can set up solar panels in the roof of every house to produce electricity. The nations that possess enough wind flow can set up large wind farms to produce electricity. Those who have capacity of producing hydro-electricity can set up dams and produce electricity. Buildings should be designed and constructed such a way that create all of their own energy from locally available renewable energy sources and served as both “power plants” and habitats. The produced electricity will transfer into micro-power plants and then transfer this to high-voltage national grid [98, 133].

Pillar 3: At night sunlight is not found, sometimes wind has no flow; water table may be below due to climate change and unable to produce hydro-electricity. To storage surplus electricity, we use hydrogen, which is considered as the universal medium, and other storage technologies, such as batteries, differentiated water pumping, and other media as the linchpin of the storage network. To maximize renewable energy and to minimize cost it will be necessary to develop new storage technologies. Surplus electricity let to flow through the hydrogen in water to be siphoned out into tank. During shortage period transfer that storage electricity back to green energy [98, 133].

Pillar 4: We share green electricity off-the-shelf IT and internet technology. By the use of Internet technology energy can be shared to the power grid of every continent and then to the world’s power grid just as like the Internet. Transform the grid and electricity

transmission line into an energy internet. Millions of buildings, offices, factories, etc. will supply surplus electricity through energy internet to the whole world. These inter-grids will revolutionize the way of electricity is produced and supplied [98, 133].

Pillar 5: Plug in electric and hydrogen fuel cell vehicles to every building for powering vehicles. The vehicles supply surplus energy back to the grid [98, 133].

Application of these five pillars will decrease on the dependence on the fossil fuels and the world will develop in a sustainable way.

8. Crises in the IR3

During the IR3 global climate has changed. Many living species have abolished and more species will vanish in near future [79]. At the end of IR3 unemployment is increasing alarmingly all over the world. The gap between the rich and the poor are widening. The standards of living are declining in most of the regions of the world [80]. More than one billion of the populations of the world have to face hunger and starvation. Eight interdependent crises in the IR3 are: i) demographic explosion and rapid consumer growth, ii) current value, ethics and necessary changes, iii) financial, economic and social crises, iv) food and nutrition crisis, v) water shortage, vi) climate change, vii) energy disaster and the change in global money streams, and viii) political disintegration [99].

Population size of the world swings at differing rates in differing regions. World population was 310 million in 1000, 461 million in 1500, 1 billion in 1800, 1.6 billion in 1900, over 6 billion in 2000 [29]. In 2021, the population becomes more than 7.9 billion and it is estimated that it will become 9-10 billion by 2050 [143]. During the 20^{th} century, the population of the world has increased enormously without fluctuation. As the mortality rate has decreased due to developed sanitation, medical progresses, and a massive increase in agricultural output [94]. For the growing population the world faces numerous problems, such as conflicts over food, water, energy, open space and wilderness, transportation infrastructure, educational space, climate change, etc. [27].

The growth rate increases due to the rise in life expectancy in many countries of the world. Most of the Asian and African countries gradually become richer. Child death rates in these countries reduce due to better medical delivery; also the birth rates drop as family will be unable to bear the responsibility of more children [99]. The rising population will create more demand on various foods. The production of biofuels will raise demand for grain. Food production has not improved in Sub-Saharan Africa for the more efficient use of land due to ownership, regulation and law, wars, and water scarcity [83]. There became a global food crisis in 2008 and the price of food rose dramatically in many parts of the world. In 2020 and 2021, COVID-19 pandemic has created serious problem in global food security and nutrition. About 811 million people in the world faced hunger in 2020 due to COVID-19 pandemic. At present about one-seventh of the global populations (about 1 billion) face hunger and starvation [35].

Of the global water supplies, 97.5% is salt and only 2.5% is fresh water. From this fresh water about 70% is used in agriculture, 20% in industry and 10% in household purposes. Fresh water is not distributed evenly in every nation. It is estimated that about 1.8 billion people of the world could have acute fresh water shortages by 2025. The demand for fresh water has increased for the growing world population, biofuel production, climate change, urbanization, dietary change, and economic growth. Global demand for fresh water will increase due to rapid growing populations and will also increase per capita consumption. There will be run short of fresh water for the urbanization [31].

9. Effects of IR3

The IR3 has changed the global society. It has both positive and negative effects. But positive effects are more fruitful than negative effects. As a result, global humanity gains boon from the IR3.

9.1. Positive Effects of IR3

The IR3 has affected every sector of the modern society. It has used advanced technology and the explosion of knowledge in ICT, transportation, advanced manufacturing, distribution, consumption, medical and health, education, agriculture, construction, defense, business, economic activities, administration, etc. There is a vast increase in wealth, the huge production of goods and materials, and the standard of living, etc. have happened during the IR3. The IR3 has created more value in business for workers and create more jobs [82]. During the IR3 most people got healthier diets, better housing, and cheaper goods. It increases mass production to meet the requirements of individual needs [61].

9.2. Negative Effects of IR3

The IR3 is reducing the consumption of the energy and raw materials and increasing the carbon footprint of manufacturing. It also has created heavy pressure on the world economics, and budget deficits in many countries. During the IR3 child labor has increased, harsh and unsafe working conditions increase in factories. Machines have taken many workers' lives [61]. It has created various challenges worldwide, such as water and air pollution, reduction of biodiversity, destruction of habitat, greenhouse gas emissions, global warming, and climate change, etc. [82].

10. Conclusion and Recommendations

In this study we have tried to discuss various sides of the third industrial revolution (IR3). In the IR1, only the Great Britain had advanced and the rest of the world was poor. In the IR2, there became a revolutionary change only in the USA. In the IR3, developments are touched in every nation and global humanity has benefited. There is an enormous change during the IR3. It is clear that in the IR3 there are revolutionary developments in education, information and communication technologies (ICT), defense, health, education, financial, and administrative sectors. It is considered as the move from mechanical and analogue electronic technology to digital electronics. In the study, we have observed that great

inventions in IR3 are semiconductors, mainframe computer, microprocessors, MOS transistors, worldwide web, internet, renewable electricity, e-commerce, and smartphone. During the IR3, environment pollutions, biodiversity reduction, greenhouse gas emissions, global warming, climate change, etc. have created serious problems in the sustainability of all living species in the 21st century.

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