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Literature Review On Challenges And Life Alterations In The Fourth Industrial Revolution In Context To Developing Countries.

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Abstract
The Fourth Industrial Revolution (4IR) is characterised as a disruptive period propelled by advanced technologies including artificial intelligence (AI), robotics, and the Internet of Things (IoT)(Schwab, 2016). It is frequently depicted as a transformative change that will revolutionise our living, working, and interaction paradigms. This narrative has encountered much criticism from multiple perspectives. Industry 4.0 signifies the integration of physical and digital realms, representing the subsequent evolution in unifying traditional and contemporary industrial technology(Fourth Industrial Revolution | Epo.Org, n.d.). This will culminate in the "Smart Factory," distinguished by versatility, resource efficiency, ergonomic design, and direct integration with manufacturing partners. The main purpose of this research is to understand the basic concepts of fourth industrial revolution, its impact on developing countries, the business model to integrate the society with new technology, major criticism highlighting its effect on various key stakeholders of society and other agencies.

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I. Introduction

The velocity and magnitude of the transformations resulting from the fourth industrial revolution must not be overlooked. These alterations will result in transformations in power, wealth, and knowledge. Only by understanding these changes and their rapidity can we guarantee that advancements in knowledge and technology are accessible and beneficial to everyone (*The Fourth Industrial Revolution: What It Means and How to Respond | World Economic Forum*, n.d.). The inaugural industrial revolution commenced in 1760 with the creation of the steam engine. The steam engine facilitated the shift from agrarian and feudal societies to industrial manufacturing processes. This transition involved the utilisation of coal as the primary energy source, with trains serving as the principal mode of transportation. The textile and steel sectors were preeminent in employment, production value, and capital investment. The second industrial revolution commenced in 1900 with the creation of the internal combustion engine. This resulted in a period of swift industrialisation utilising oil and electricity to facilitate mass production. The third industrial revolution commenced in 1960 and was marked by the integration of electronics and computer technologies to automate manufacturing processes. Traditionally, manufacturing required the assembly of numerous components through screwing or welding. The fourth industrial revolution encompasses computer-generated product design and three-dimensional (3D) printing, which fabricates solid objects by incrementally layering materials (*Full Article: Towards a 4th Industrial Revolution*, n.d.)

II. Literature Review

From 1760's till the present day.

The fourth industrial revolution has bestowed numerous technical achievements upon human civilisation. Consider it a significant advancement, building upon the preceding digital revolution. This era is propelled by advancements such as artificial intelligence, robotics, the Internet of Things (IoT), biotechnology, and quantum computing, which are integrating the physical, digital, and biological domains in ways we are only beginning to comprehend (Siemieniuch et al., 2015). Klaus Schwab, who originated the phrase, described it as a "technological revolution that will fundamentally transform our modes of living, working, and interpersonal relations." The essence is that it transcends mere technological innovations; it represents a systemic transformation (Stearns, 2018) . Artificial intelligence enhances Internet of Things analytics, quantum computing accelerates AI training, and biotechnology relies on computer capacity. This combination is the true catalyst for transformation.

Agents Propelling the Fourth Industrial Revolution

Digitisation and Integration of Vertical and Horizontal Value Chains:

Industry 4.0 digitises and vertically integrates activities throughout the business, encompassing product development, procurement, manufacturing, and logistics. All information on operational processes, process efficiency, quality management, and operations planning is accessible in real-time, enhanced by augmented reality and optimised inside an integrated network (Ferreri et al., 2018). Horizontal integration extends beyond internal operations, encompassing suppliers, customers, and other essential value chain partners. It encompasses technology ranging from track and trace devices to real-time integrated planning and execution (López Martínez et al., 2021).

Digitalisation of Product and Service Offerings

The digitisation of products include the enhancement of current items, such as the incorporation of smart sensors or communication devices compatible with data analytics tools, and the development of new digital products that emphasise fully integrated solutions.(Moch, 2024) Through the integration of novel data collecting and analysis techniques, organisations can produce insights on product utilisation and enhance products to satisfy the growing demands of end-users (Belvedere et al., 2013).

Digital Business Models and Consumer Accessibility

Prominent industrial firms augment their offerings by delivering transformative digital solutions, including comprehensive, data-driven services and integrated platform solutions.

Digital business strategies mostly concentrate on earning supplementary digital revenues and enhancing client contact and accessibility. Digital products and services often aim to provide customers with comprehensive solutions inside a specific digital environment (Strubell et al., 2019). The developed AI has established a fundamental requirement for human interaction tools, significantly enhancing the ease of life. At its essence, artificial intelligence (AI) encompasses not only chatbots such as me but also systems that learn, anticipate, and optimise various domains, including manufacturing processes and medical diagnostics. Machine learning and deep learning are the primary technologies, analysing extensive datasets to identify patterns beyond human capability (Zhao et al., 2019).

Crux of 4IR growth

The Internet of Things (IoT) refers to the interconnection of physical devices. It provides connectivity among systems, services, and devices that transcends machine-to-machine communication, encompassing a diverse array of protocols, domains, and applications. This automation is essential for the advancement of smart grids, which consequently fosters the tangible realisation of smart cities (Chen, 2012). The Internet of Things (IoT) integrates numerous connected devices, ranging from smart thermostats to sensors in shipping containers, which transmit data to the cloud for continuous optimisation(Bandyopadhyay & Sen, 2011).

3D printing diminishes the obstacles between inventors and markets. It enables entrepreneurs with innovative concepts to launch small enterprises with reduced start-up expenses, conserving time and resources, hence facilitating entry into the market (Xu et al., 2018a). Robotics is a flourishing component of the fourth industrial revolution, permeating every facet of our lives. It lacks a visage yet possesses the capacity to enhance the quality of our lives. Customised robots will generate additional employment opportunities and enhance the quality and productivity of current positions. Biotechnology represents a distinct domain—CRISPR gene editing and synthetic biology enable us to manipulate life itself, whether for the treatment of genetic disorders or the production of lab-cultivated meat (Xu et al., 2018a; Zonta et al., 2020). Quantum computing is in its nascent stages, however it holds the potential to resolve challenges (such as medicine discovery or climate modelling) that would need contemporary computers millennia to address (Graetz & Michaels, 2018).

The convergence of technology is obscuring the distinctions of physical, digital, and biological domains. It generates new markets and opportunities for everyone participant in the field of innovation (*THE FOURTH INDUSTRIAL REVOLUTION: SHAPING A NEW ERA - ProQuest*, n.d.). This revolution has facilitated the integration of diverse fields to produce various items effortlessly.

Developing Nations with 4.0 Capability

The Fourth Industrial Revolution (4IR) is transforming the global landscape, with countries responding in diverse manners influenced by their resources, policies, and technological capabilities. The advancement is propelled by advances such as artificial intelligence, robots, the Internet of Things, and biotechnology; hence, a nation's standing frequently depends on its capacity to accept and develop with these technologies (Avgerou & Walsham, 2017).

The United States excels in artificial intelligence and quantum computing, driven by substantial research and development expenditure and an ability to attract international talent, exemplified by Silicon Valley's allure for engineers globally (Johnson et al., 2013). China is closely following, investing billions in artificial intelligence, 5G, and quantum technology, exemplified by state-sponsored initiatives such as the National Laboratory for Quantum Information Sciences (*What Is the Fourth Industrial Revolution and Its Technologies - Iberdrola*, n.d.). They are in close competition with the U.S. in several domains, utilising a centralised strategy to surpass others in both scale and speed. Germany introduced the "Industrie 4.0" idea, emphasising intelligent production; businesses such as Siemens are equipping factories with IoT and automation, maintaining its status as a pioneer in industrial technology.

Japan is another significant contender, distinguished in robotics and precise manufacturing. In response to an ageing population, there is a reliance on Fourth Industrial Revolution technology to address labour shortages—envision "Society 5.0," wherein artificial intelligence and robotics sustain economic activity. South Korea is actively advancing in 5G and semiconductors, whereas Switzerland integrates high-tech innovation with initiatives such as "Industry 2025" to maintain competitiveness (Xu et al., 2018a).

The intermediate tier comprises nations such as the United Kingdom, Canada, and Singapore. The UK excels in fintech and artificial intelligence, yet it is lagging in industrial technology. Canada is a centre for AI research, particularly in Toronto, and blockchain technology; yet, it is less proactive in scaling production. Singapore distinguishes itself by leveraging its compact size through intelligent urban initiatives and a comprehensive adoption of Fourth Industrial Revolution policies, focussing on speed and systemic influence (Ross & Maynard, 2021).

Developing nations and the Fourth Industrial Revolution (4IR) embody a compelling combination of promise and difficulty. These nations—predominantly in Africa, Asia, and Latin America—are entering a realm propelled by AI, robots, IoT, and biotechnology, although they commence from a distinct baseline compared to the worldwide frontrunners. Their Fourth Industrial Revolution journey focusses more on utilising new technologies to surpass conventional development obstacles, however the path is fraught with challenges(Drath & Horch, 2014).

Developing countries present a contrasting narrative. India possesses a burgeoning digital economy and industrial infrastructure, capitalising on inexpensive labour and an expanding technology sector to engage in the Fourth Industrial Revolution—encompassing factory digitisation and an impetus for artificial intelligence companies . Rwanda is gaining prominence in Africa with its Centre for Fourth Industrial Revolution, investing in drones and artificial intelligence to overcome infrastructure deficiencies. Ethiopia is utilising blockchain technology for coffee exports, demonstrating how the Fourth Industrial Revolution might enhance agriculture (Lechman, 2017). However, several least-developed countries (LDCs) are significantly behind—merely one in six individuals in the most impoverished nations possesses internet access, while patents for Fourth Industrial Revolution technology are predominantly controlled by a select few, with 90% held by only 10 countries, including the United States, Japan, and China (Ross & Maynard, 2021).

The Narrative of India

India serves as a prominent exemplar. It possesses a substantial population, an expanding technology industry, and a rapidly burgeoning digital economy—consider UPI, the world's largest real-time payment system, processing billions of transactions each month . India is advancing artificial intelligence in healthcare, exemplified by businesses employing machine learning for diagnostics, and in manufacturing, particularly through smart factories in Tamil Nadu, leveraging its information technology expertise and cost-effective labour (Jadhav et al., 2019). The government's "Digital India" effort is connecting rural regions, while programs such as "Make in India" seek to modernise manufacturing through Fourth Industrial Revolution technologies. Nonetheless, obstacles persist—Forty percent of the workforce is engaged in agriculture, predominantly utilising poor technology, while infrastructural deficiencies impede the implementation process.

The Narrative of Rwanda

Rwanda is a prominent nation in Africa. Although modest in size, it is ambitious, positioning itself as a technological hub with its Centre for the Fourth Industrial Revolution, inaugurated in collaboration with the World Economic Forum. Drones represent a significant advancement—Zipline transports medical supplies to remote hospitals, reducing hours-long journeys to only minutes. Rwanda is digitising governance with blockchain and artificial intelligence, seeking to overcome decades of lagging progress. Internet penetration has surged from 8% in 2010 to over 50% currently; nonetheless, challenges persist, including inadequate rural connection, insufficient skills training, and limited funding.

Ethiopia's Narrative

Ethiopia is exploring the Fourth Industrial Revolution by utilising blockchain technology to monitor coffee exports, a significant sector of its economy. It is a component of the comprehensive "Digital Ethiopia 2025" initiative aimed at modernisation; nevertheless, just 25% of the population is online, and the industrial capacity remains rudimentary, primarily focused on textiles and leather rather than robotics. The possibility exists; inexpensive labour and renewable energy might entice Fourth Industrial Revolution investment if managed effectively.

Countries of South Asia and Latin America

Vietnam is gaining attention in Southeast Asia. It is a manufacturing hub, particularly for Samsung electronics, integrating IoT and automation into factories to ascend the value chain. The government aims to achieve "Industry 4.0" status by 2030; however, education is a bottleneck as STEM skills are not meeting demand. Indonesia faces analogous challenges, characterised by a substantial youthful demographic and an initiative for "Making Indonesia 4.0," which encompasses advanced logistics and digital payment systems; yet, inconsistent infrastructure and regulatory disarray impede progress (Lechman, 2015).

Latin America features teams such as Brazil and Mexico. Brazil employs AI in agribusiness using drones for crop monitoring and in finance; nevertheless, political instability and educational disparities impede progress. Mexico is integrated into U.S. supply networks and is using automation in automotive manufacturing; yet, it has challenges in technology adoption outside urban centres (Lechman, 2017).

The disparity is pronounced. Advanced economies in Europe, North America, and East Asia—approximately 25 nations—propel the majority of advancement, according to the World Economic Forum's preparedness surveys. Countries such as Estonia advanced into the digital era following the Soviet period, establishing "e-Estonia" with AI-driven administration (Liao et al., 2017). In contrast, much of Africa and certain regions of Southeast Asia prioritise achieving the foundational aspects of the Third Industrial Revolution—basic electricity and digitization—before addressing the cyber-physical systems of the Fourth Industrial Revolution (Stern & Kander, 2012). The patterns across these countries are very disparate; they are not innovating 4IR technology—90% of pertinent patents are held by the U.S., China, Japan, and others—but rather, they are adopting it (Bahrin et al., 2016). Success in development is realised through connectivity (internet access remains below 20% in numerous LDCs), skills (coding surpasses subsistence farming in this context), and policy (governments must attract investment while avoiding excessive regulation)(Liao et al., 2018). Reliance on advanced technological nations becomes crucial for fundamental needs, as there is a risk of being increasingly marginalised as the affluent prosper from exponential technology.

III. Analysis And Findings:

The rapid advancement of the Fourth Industrial Revolution suggests that latecomers may potentially circumvent some stages, similar to how mobile phones supplanted landlines in various areas (Xu et al., 2018a). However, this necessitates investment in talents, infrastructure, and policy. In its absence, the chasm widens.

Numerous problems must be overcome to ensure the successful deployment of sophisticated technologies and the realisation of Industry 4.0's potential.

Several key issues are outlined below:
Absence of a specific digital strategy
Insufficient data analytical capabilities
Cultivating a robust digital culture
Degree of digitisation
Information Protection
Absence of standardisation

Evolution rather than Revolution

A prominent objection is that the Fourth Industrial Revolution is not genuinely a separate revolution. Critics contend that it is simply an extension of the Third Industrial Revolution, which introduced digital technology and automation in the late 20th century (Moll, 2021). They argue that the breakthroughs we are witnessing—such as artificial intelligence and intelligent systems—represent incremental enhancements rather than a fundamental departure from the past. This viewpoint implies that designating it as a "fourth" revolution may be more of a catchphrase than an indication of a truly novel epoch (Xu et al., 2018a). The fourth Industrial Revolution is likely an intensified version of the Third Industrial Revolution. In comparison, the First Industrial Revolution transitioned civilisations from rural to industrial economies. The Second Industrial Revolution introduced assembly lines and widespread electricity, transforming daily life (Coleman, 1956).

The Fourth Industrial Revolution is not a discrete revolution; it is predicated on the notion that it does not represent a clear separation from the past. Instead of presenting completely novel technology or societal transformations, it expands upon the digital underpinnings of the Third Industrial Revolution, augmenting and expediting them (Hongladarom, 2023). Critics saw it as an evolutionary stage—more rapid and widespread, indeed—but not a revolutionary advancement. The validity of this perspective hinges on our definition of "revolution," although it is evident that for some, the Fourth Industrial Revolution represents not a new chapter, but rather a continuation of the existing digital narrative (Moll, 2021).

A Promotional Strategy

Some sceptics perceive the Fourth Industrial Revolution as a marketing tactic rather than a genuine socioeconomic transformation. They contend that consultants, technology firms, and thought leaders amplify its importance to generate excitement, stimulate sales, and compel enterprises to embrace new goods and services (Erevelles et al., 2016) . The apprehension of "missing out" on this purported revolution compels organisations to invest, despite the improvements not being as dramatic as claimed (Su et al., 2020). This is not a novel phenomenon. Other technological advancements have seen analogous critiques as mere "marketing ploys":

• Dot-Com Bubble (Late 1990s): The internet was promoted as a transformative revolution, inciting a surge of investment in online enterprises—numerous of which failed when expectations did not align with reality.

• Blockchain Enthusiasm: Blockchain technology and cryptocurrencies were previously promoted as revolutionary agents for banking and other sectors. Although they possess potential, the initial enthusiasm frequently exceeded their tangible advancement, driven by supposition (Su et al., 2020).

The Fourth Industrial Revolution is not merely illusory; its technologies are significant and warrant careful consideration. Nonetheless, the word can effectively serve as a marketing strategy, employed to enhance urgency, generate revenue, and promote solutions (Erevelles et al., 2016) . It is essential to use a critical approach: dismantle the exaggeration, evaluate the genuine worth of the modifications, and refrain from succumbing to every buzzword-laden proposal. Disregarding advancement is unwise, yet so is hastily embracing every trend deemed "revolutionary." (Liao et al., 2017)

Aggravating Disparity

A significant issue is the potential for the Fourth Industrial Revolution to exacerbate economic and social inequality. Individuals possessing sophisticated technical abilities may excel in this technology-centric environment, whereas employees in positions susceptible to automation, such as manufacturing or repetitive service functions, confront job displacement and economic instability (Jones, 2001) . This polarisation engenders a digital divide, wherein the advantages of innovation disproportionately benefit the affluent and highly trained, therefore neglecting low-skilled workers and marginalised populations (Siemieniuch et al., 2015).

Economic Disparity: Beneficiaries and Victims

The Fourth Industrial Revolution is set to revolutionise the labour market, although not all individuals will benefit equally (Helpman & Trajtenberg, 1996).

• Job Automation: Technologies such as artificial intelligence and robotics have the capacity to supplant repetitive or routine occupations, including manufacturing personnel, cashiers, and truck drivers (*23+ Artificial Intelligence And Job Loss Statistics [2023]: How Job Automation Impacts the Workforce - Zippia*, n.d.). A research estimates that as many as 47% of employment in the United States may be susceptible to automation. Low-skilled workers, frequently devoid of retraining facilities, thus encounter unemployment or underemployment (Frey & Osborne, 2017a).

• High-Skill Premium: Concurrently, positions associated with the development, management, or utilisation of these technologies—such as software engineers or data scientists—are in significant demand and command elevated salaries. This engenders a skills disparity, wherein individuals possessing advanced education or technical training prosper, while others have stagnant or diminishing salaries (Zonta et al., 2020).

• Wealth Concentration: The corporations propelling the Fourth Industrial Revolution—such as Google, Amazon, and Tesla—generate substantial profits, thereby consolidating wealth among shareholders and management (Valente, 1996). Workers displaced by automation, however, do not partake in these benefits, exacerbating the disparity between the "haves" and "have-nots." (Muhuri et al., 2019)

The Disparity in Digital Access

Access to the tools of the Fourth Industrial Revolution is not ubiquitous, exacerbating inequality:

• Technology Access: High-speed internet, intelligent gadgets, and advanced software are essential for engagement in this emerging economy. However, rural regions, developing nations, and low-income people frequently lack dependable connectivity(Liao et al., 2018). For instance, millions remain without broadband access, so excluding them from online education and remote employment options facilitated by Fourth Industrial Revolution technologies.(Avgerou & Walsham, 2017)

• Educational Disparities: Acquiring skills in coding, data analysis, or artificial intelligence necessitates schooling, which is sometimes costly and inaccessible for marginalised population (Zhang et al., 2019). Affluent individuals or areas can access premier educational institutions or training programs, but others are relegated to obsolete or insufficient resources, so creating a cycle of exclusion. (Underwood, 2007)

Socioeconomic and Geographic Disparity

The advantages of the Fourth Industrial Revolution are not uniformly allocated among cultures or locations.

• Urban vs. Rural: Urban areas typically serve as centres for technological innovation, drawing investment and skilled individuals (Johnson et al., 2013). Rural regions, however, may have limited enhancements, resulting in economic stagnation as employment and opportunities concentrate in urban areas (Lechman, 2015).

• Global North versus South: Developed countries, possessing existing infrastructure and capital, are more favourably situated to implement Fourth Industrial Revolution technology (Lechman, 2017). Conversely, developing nations may have challenges in maintaining competitiveness, either leading to exploitation as inexpensive labour sources or missing opportunities for progress entirely.

Practical Illustrations

• Gig Economy: Platforms such as Uber and Deliveroo, driven by Fourth Industrial Revolution technology, provide flexible employment yet frequently lack benefits and job stability. Employees receive less stable remuneration, whilst corporations reap substantial profits (Drath & Horch, 2014).

• AI in Recruitment: Algorithms can enhance the hiring process but may preferentially select people with digital footprints or qualifications that under-represented groups are less likely to possess, so perpetuating bias and exclusion (Liao et al., 2017).

When significant segments of the population see neglect, animosity develops, potentially inciting social upheaval or political division (Belvedere et al., 2013). A diminishing middle class undermines consumer demand, potentially hindering growth over time. The promise of development in the Fourth Industrial Revolution is unconvincing if it primarily advantages a select elite at the expense of others (Asghar et al., 2020). The Fourth Industrial Revolution may generate opportunities, such as positions in green technology or remote employment, that elevate individuals (Ross & Maynard, 2021). Critics argue that the current rate of change is more rapid, and the requisite skills are increasingly specialised, complicating adaptation for the average worker without substantial assistance (e.g., retraining initiatives or universal basic income) (*The Jobs Most Likely to Be Lost and Created Because of AI | World Economic Forum*, n.d.). In the absence of intentional measures to address the skills gap, enhance accessibility, and redistribute benefits—via policy or innovation—the Fourth Industrial Revolution may exacerbate disparities instead of alleviating them (Frey & Osborne, 2017b). The technology itself is not intrinsically unfair; rather, the mechanisms implementing it frequently exacerbate existing imbalances, prompting society to consider if development incurs an excessive cost for many (de Witte et al., 2016).

Risks Associated with Data Privacy and Security

The Fourth Industrial Revolution's dependence on networked devices and extensive data accumulation presents significant privacy and security issues. As AI and IoT systems accumulate unparalleled volumes of personal data, there exists a possibility that such information may be utilised by large technology firms or governmental entities for purposes of monitoring, manipulation, or profit (Jones, 2001). Critics interrogate the true custodians of this information and if individuals can preserve autonomy in an ever-more interconnected environment (Dreyer et al., 2006). The reliance of the Fourth Industrial Revolution on interconnected systems and extensive data flows generates vulnerabilities that jeopardise individual autonomy, disclose sensitive information, and facilitate exploitation by corporations, governments, or nefarious entities. (Hongladarom, 2023)

The Proliferation of Data

The Fourth Industrial Revolution relies on data, frequently referred to as the "new oil." (Stach, 2023) Smart devices, including wearables and home assistants, continuously produce streams of personal data:

• IoT Devices: Your intelligent thermostat monitors your habits, your fitness tracker records your health metrics, and your linked vehicle documents your travels.(Bandyopadhyay & Sen, 2011)

• AI Systems: Algorithms require extensive datasets for learning and prediction, incorporating everything from surfing behaviours to social media activity. (Johnson et al., 2013)

Risks to Privacy

• Loss of Control: Individuals frequently lack a comprehensive understanding of the data collected and its utilisation. The terms of service are lengthy and ambiguous, providing users with minimal control over their information (Erevelles et al., 2016). A smart speaker may capture conversations beyond its activation phrase, often without your awareness.

Surveillance Capitalism: Corporations such as Google and Amazon utilise this data to create profiles, anticipate preferences, target advertisements, and perhaps manipulate behaviour. Shoshana Zuboff's The Age of Surveillance Capitalism Capitalism (2019) cautions that this transforms personal data into a commodity, undermining privacy for profit.(Zuboff, 2019)

• Government Overreach: In many nations, Fourth Industrial Revolution technology facilitates extensive surveillance. China's social credit system, utilising facial recognition and data integration, monitors individuals' actions, administering penalties or rewards contingent upon their behaviour (López Martínez et al., 2021). In democracies, agencies may access private data with less scrutiny (Jadhav et al., 2019).

Security Flaws

The interrelated characteristics of Fourth Industrial Revolution technology exacerbate security vulnerabilities:

• Prevalent Vulnerabilities: The Internet of Things comprises billions of devices, many of which exhibit inadequate security measures (Atzori et al., 2010). A compromised smart lock or camera may grant intruders actual entry to your residence. In 2016, the Mirai botnet leveraged insecure IoT devices to execute a substantial hack, demonstrating the susceptibility of these systems (Bennett et al., 2008).

• Data Breaches: The centralised storage of sensitive information, such as health records or financial details, renders it an attractive target for hackers . Notable breaches, exemplified by the 2017 Equifax incident that compromised the data of 147 million individuals, illustrate the vulnerabilities of ostensibly "secure" technologies in the context of the Fourth Industrial Revolution's magnitude (Balogun et al., 2023).

• Supply Chain Vulnerabilities: The intricate supply chains of global technology mean that a single compromised element—such as a chip in a smart device—can jeopardise entire networks (Srnicek, 2017) . The 2020 SolarWinds breach, which compromised governmental and corporate networks, underscores this threat.

The hazards arise from various stakeholders:

• Technology Corporations: Numerous entities prioritise functionality and profitability over comprehensive security, hastily launching goods with inherent flaws. Privacy policies frequently prioritise the interests of the firm over those of the user (Erevelles et al., 2016).

• Authorities: There is a delay in the regulation of data utilisation, while others utilise it for dominance. (Balogun et al., 2023)

• Users: A deficiency in awareness or negligence—such as the reuse of passwords—exacerbates the issue, while critics contend that individuals should not be held accountable for systemic deficiencies.(Moch, 2024)

Practical Consequences

These risks are not hypothetical; they are already manifesting significantly.

• Identity Theft: Compromised data facilitates fraud, resulting in annual losses amounting to billions and devastating lives.(López Martínez et al., 2021)

• Manipulation: The Cambridge Analytica incident demonstrated how collected data may influence elections, so compromising democracy.(Xu et al., 2018a)

• Physical Harm: Compromised medical devices (e.g., insulin pumps) or driverless vehicles may become lethal if security measures are inadequate. (Moll, 2021)

The Fourth Industrial Revolution's amalgamation of physical and digital realms—such as smart cities or biometric identification—implies that breaches not only compromise passwords but also reveal your location, health, and behaviours (Balogun et al., 2023). The magnitude and velocity of data transmission surpass conventional protections, resulting in regulators and security professionals struggling to keep pace.

The dependence of the Fourth Industrial Revolution on data is a double-edged sword. It drives advancement yet unveils a Pandora's box of privacy and security hazards, including mass spying, corporate exploitation, and cyberattacks (Liao et al., 2018). In the absence of robust safeguards—such as enforced rules, enhanced design standards, or user empowerment—the Fourth Industrial Revolution may sacrifice control for convenience, rendering humans vulnerable in an environment where every action, movement, and heartbeat is susceptible to exploitation (Schwab, 2016). The inquiry pertains to whether society can utilise these instruments without compromising our fundamental human rights which are privacy and safety.

Ecological Consequences

The environmental sustainability of the Fourth Industrial Revolution is frequently neglected. The manufacturing and operation of sophisticated technologies necessitate substantial energy and natural resources; nonetheless, dialogues regarding the revolution seldom emphasise ecological ramifications. Critics caution that neglecting sustainability may exacerbate resource depletion and exacerbate climatic issues, jeopardising the long-term viability of the Fourth Industrial Revolution (4IR)

Extraction and Depletion of Resources

The Fourth Industrial Revolution depends on hardware—such as servers for artificial intelligence, sensors for the Internet of Things, and batteries for robotics—that necessitates raw materials, many of which are limited (Belkhir & Elmeligi, 2018).

- Rare Earth Elements: Devices require metals such as lithium, cobalt, and neodymium, which are extracted by environmentally detrimental methods. Cobalt extraction in the Democratic Republic of Congo frequently results in deforestation, water pollution, and habitat destruction.(Belkhir & Elmeligi, 2018)
- Magnitude of Demand: The growth of smart devices—estimated to be billions of IoT gadgets—exacerbates this extraction. A solitary smartphone may appear diminutive, yet the annual production of billions exerts pressure on global resources and ecosystems. (Malmodin & Lundén, 2018)

Energy Utilisation

The digital infrastructure of the Fourth Industrial Revolution is energy-intensive.

- AI Training: The training of a single large AI model can produce carbon emissions equivalent to those of five automobiles during their lifespan (Strubell et al., 2019). Data centres operating these models consume substantial electricity, frequently derived from fossil fuel sources.
- Internet of Things Networks: Billions of interconnected gadgets require continuous power and bandwidth (Bahrin et al., 2016). Although each consumes minimal energy independently, the aggregate impact is substantial.
- Cryptocurrency and Blockchain: Certain technologies associated with the Fourth Industrial Revolution, such as blockchain (used in supply chains or digital currencies), are notoriously energy-intensive (Zhuk, 2023). Bitcoin mining consumes more electricity annually than certain nations.

E-Waste Dilemma

The swift advancement of Fourth Industrial Revolution innovations hastens obsolescence.

- Brief Lifecycles: Smartphones, wearables, and IoT gadgets are regularly changed, resulting in an accumulation of electronic trash. In 2019, the global production of e-waste reached 53.6 million metric tonnes, predominantly from Fourth Industrial Revolution technologies, with merely 17% being recycled appropriately (Zhuk, 2023). Toxic Legacy: Discarded electronics release dangerous substances—lead, mercury, cadmium—into soil and water, particularly in developing countries where e-waste is frequently disposed of (Beloglazov et al., 2011). This contaminates ecosystems and populations.

Production Footprint

- 3D Printing: Although it minimises waste in certain instances, it frequently utilises plastics sourced from fossil fuels, and the energy consumption of printers may surpass the advantages (Widmer et al., 2005).
- Automation: Robotic factories may enhance productivity but remain dependent on energy-intensive methods, frequently fuelled by coal or gas in areas with polluted electricity networks. (Belkhir & Elmeligi, 2018)

Concealed Expenses of "Intelligent" Systems

The concept of the Fourth Industrial Revolution for smart cities and industry appears efficient; nevertheless, the actual situation is more complex.(Valente, 1996)

- Rebound Effects: Intelligent technology may conserve energy in one domain (e.g., smart thermostats) while promoting excessive use in another (e.g., increased number of gadgets per household), so nullifying benefits.(Shah et al., 2010)
- Infrastructure Development: The deployment of 5G networks or IoT grids necessitates the installation of new towers, cables, and satellites, each imposing its own environmental impact—land utilisation, emissions, and space debris (Belkhir & Elmeligi, 2018; Xu et al., 2018a).

Connection to Climate Change

The environmental concerns of the Fourth Industrial Revolution are closely linked to global warming. The ICT sector, crucial to the Fourth Industrial Revolution, may contribute to 20% of world emissions by 2030 if left unregulated (Belkhir & Elmeligi, 2018; Xu et al., 2018b). That constitutes a substantial portion of carbon emissions.

- Feedback Loops: Increased technology use results in heightened energy consumption, which, in the absence of a transition to renewable sources, perpetuates elevated emissions, hence exacerbating climate effects such as floods and heatwaves that disproportionately affect vulnerable populations (Malmodin & Lundén, 2018).

The environmental risks of the Fourth Industrial Revolution—encompassing resource extraction, energy consumption, waste generation, and emissions—diminish its appealing promises. The technology can contribute to a more sustainable future; yet, its current implementation frequently emphasises speed and size at the expense of sustainability. If unregulated, the Fourth Industrial Revolution could exacerbate the ecological problem, sacrificing long-term sustainability for immediate benefits.

Effects of the fourth industrial revolution on people and society

At a never-before-seen rate, the Fourth Industrial Revolution (4IR), which is defined by the convergence of technologies like biotechnology, robots, artificial intelligence (AI), and the Internet of Things (IoT), is changing social structures and human existence (Johnson et al., 2013). This analysis, which is based on recent studies and publications, provides a thorough analysis for a wide audience by examining its complex effects on labour markets, health, social relationships, government, privacy, education, the economy, and the environment.

Impact on Health and Well-Being

AI-driven diagnostics and personalised treatment have been shown to improve health outcomes, however sedentary habits and increasing screen time may be detrimental to mental health (Best et al., 2014). According to a 2018 poll (Consumer Tech Dependency poll), 32% of people check their phones as soon as they get up (Kim et al., 2020). Complexity is increased by ethical discussions around gene editing.

According to NPR and MIT Technology Review articles, 4IR technologies are improving health outcomes, with AI helping with diagnostics, tumour detection, and Alzheimer's management (AI can spot signs of Alzheimer’s before your family does, and doctors see promise in AI for some hard-to-find tumours). Accessibility is improved via telemedicine and personalised medicine, especially in rural regions. Increased screen time and sedentary lifestyles, however, can be harmful; according to a 2018 Asurion poll, 32% of respondents check their phones as soon as they get up, and 58% report feeling addicted (Consumer Tech Dependency poll) (Ye et al., 2023). Advances in biotechnology, such as CRISPR gene editing, pose ethical questions about access inequities and designer babies while also potentially offering treatments (Zhuk, 2023).

Another issue is mental health, as a 2023 PMC systematic review protocol (The effect of the 4th industrial revolution on family cohesiveness) noted that continuous connection may impede meaningful interactions and relationships (Balogun et al., 2023). According to World Economic Forum data, just 20% of people in the least-developed nations have internet connection, ensuring that not everyone benefits equally (Ross & Maynard, 2021).

Cultural and Social Change

Society is undergoing a complete transformation, including our relationships, economy, and government (Perez, 2009). Where 4IR technology is used, economic productivity is rising because smart factories produce items more quickly and at a lower cost. Low-skilled labourers stagnate while IT giants and sophisticated elites profit from the wealth accumulation at the top (Coleman, 1956). According to the OECD, 90% of 4IR patents are owned by only ten wealthy nations, meaning that emerging countries run the risk of being completely shut out if inequality spikes in countries that are sluggish to adapt (Asghar et al., 2020; Siemieniuch et al., 2015). Governance is also changing. Smart cities, like Singapore's real-time urban planning, leverage IoT to reduce waste or traffic. However, monitoring intrudes—China's AI-powered social credit system monitors and rates residents, demonstrating how 4IR may strengthen control (Li et al., 2024). Privacy is rapidly deteriorating; data is the driving force behind this change, and rarely anything is done to put a stop to it. (López Martínez et al., 2021) Through social media and virtual platforms, the 4IR is changing social relationships and improving global connectedness, but it may also result in less in-person engagement (Lee et al., 2014). According to study, technology may decrease family togetherness, which might lead to a decline in empathy and social skills, especially among younger generations(Agosto et al., 2012). On the other hand, it also creates new virtual communities that offer networks of support to a variety of organisations (Bala, n.d.). A 2023 research found that a continual connection to automated systems may impede meaningful talks, highlighting the importance of striking a balance between virtual and real relationships (Balogun et al., 2023).

Cultural changes include the challenge to conventional creativity posed by AI-generated art and virtual influences, as well as ethical concerns sparked by biotech issues like gene editing (Zhuk, 2023). According to Iberdrola, society must adjust to the rapid pace of change, which carries the risk of social separation brought on by autonomous labour patterns.

Privacy, Governance, and Adaptations in Education

Through effective service delivery—such as Singapore's smart city programs, which use IoT for urban planning—governance gains from 4IR (Li et al., 2024). China's social credit system serves as an example of how monitoring increases privacy issues, necessitating strict laws like the EU's General Data Protection Regulation (GDPR) to safeguard individual rights (EU GDPR) (Li et al., 2024). Salesforce's ethical AI courses are mentioned in a 2018 Medium piece that highlights business responsibilities in integrating technology with human rights

(*Human Rights in the Fourth Industrial Revolution: Industry's Role and Responsibilities | by Kathy Baxter | Salesforce Designer | Medium*, n.d.).

Because technology is developing so quickly, education must change to teach digital literacy, creativity, and critical thinking. Lifelong learning is also becoming more and more important. According to the World Economic Forum, the digital divide—which might leave many people behind—occurs in developing nations like Rwanda, where just 50% of people have access to the internet (Liao et al., 2017).

The Job Market and the Transformations of the Economy

Automation and artificial intelligence are set to displace occupations, particularly those involve repetitive activities, as a result of the Fourth Industrial Revolution, which is drastically altering employment landscapes (Frey & Osborne, 2017a). It is estimated that between 400 million and 800 million occupations might be automated by the year 2030 (Muhuri et al., 2019). This range of employment includes positions such as shop clerks and office receptionists. According to a human rights post published on Medium in 2018 titled "Human Rights in the Fourth Industrial Revolution," this displacement is not uniform, with increased dangers for workers who are young, untrained, and members of minority groups (*Human Rights in the Fourth Industrial Revolution: Industry's Role and Responsibilities | by Kathy Baxter | Salesforce Designer | Medium*, n.d.). On the other hand, the revolution also leads to the creation of new possibilities in domains connected to technology, such as data science and the development of artificial intelligence, which calls for widespread programs to reskill and upskill individuals. The research that was published by the World Economic Forum in 2023 underlines the fact that artificial intelligence huge language models might potentially affect forty percent of working hours (*23+ Artificial Intelligence And Job Loss Statistics [2023]: How Job Automation Impacts the Workforce - Zippia*, n.d.). This indicates that businesses should prioritise training for technical abilities like as AI engineering, which are the professions that are most likely to be lost or generated as a result of AI.

There is a rising worry over economic inequality, since the advantages of fourth industrial revolution may be concentrated among tech giants and talented people, leaving others behind (Liao et al., 2017). According to a research developing countries may have difficulty keeping up with its speed since only ten wealthy nations have ninety percent of the patents for the fourth industrial revolution (Xu et al., 2018b). This has the potential to expand economic differences throughout the world, which might have repercussions for social stability and access to opportunities.

Aspect	Details	Statistics/Examples
Job Displacement	Automation affects clerical, manufacturing roles.	400M–800M jobs by 2030 (Jobs of the Future: Jobs Lost, Jobs Gained | McKinsey, n.d.)
New Job Creation	Tech roles like data scientists, AI engineers emerge.	20–50M new jobs by 2030 (What Is the Fourth Industrial Revolution and Its Technologies - Iberdrola, n.d.)
Economic Inequality	Benefits may concentrate in tech hubs, widening gaps.	90% patents in 10 rich nations (Iberdrola SA, n.d.)

Considerations Regarding the Environment

Environmentally speaking, 4IR provides sustainability by means of smart grids, technologies that generate renewable energy, and precision agriculture, all of which contribute to the reduction of waste and the fight against climate change (Li et al., 2024). Nevertheless, the creation and disposal of technology, such as electronic trash, pose dangers if they are not managed properly (Widmer et al., 2005). An article highlights the possible environmental problems that might result from greater manufacture of technology at the time (Min et al., 2019). An essay published in 2021 highlights the necessity of green manufacturing strategies and regulations in order to achieve a balance between these many characteristics (Ross & Maynard, 2021).

Aspect	Details	Examples/Statistics
Governance Benefits	Efficient services via smart cities, IoT.	Singapore's real-time urban planning (Li et al., 2024)
Privacy Risks	Surveillance, e.g., China's social credit system.	EU GDPR for data protection (Erevelles et al., 2016)
Education Needs	Teach digital literacy, critical thinking.	Lifelong learning essential (Jadhav et al., 2019)
Environmental Gains	Smart grids, precision agriculture.	Reduces waste, combats climate change (Zhuk, 2023)
Environmental Risks	E-waste from tech production.	Requires green manufacturing policies (Schwartz et al., 2020)

IV. Conclusion:

On the one hand, the Fourth Industrial Revolution (also known as the 4IR) brings prospects for increased productivity, health, and connectedness; on the other hand, it also poses concerns such as the loss of jobs, the erosion of privacy, and economic inequality (Moll, 2021). For this shift to be successfully navigated, inclusive policies, ethical concerns, and sustainability initiatives are required to guarantee that benefits are distributed to a large number of people (Liao et al., 2017). Recent research highlights the necessity of adopting balanced approaches in order to capitalise on the potential of the fourth industrial revolution while simultaneously mitigating risks (Balogun et al., 2023; Min et al., 2019).

The complexity and urgency of addressing the implications of 4IR, which will ensure a future that is centred on people, is brought to light by this in-depth research, which was influenced by many academic publications, which highlights the key points narrating conceptual background of Fourth Industrial Revolution along with its impact, criticism and challenges which needs to be given much more consideration for a sustainable future leading to a value added revolution.

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