sustainability

Review

A Review on the Way Forward in Construction through Industrial Revolution 5.0

Muhammad Ali Musarat [1,2], Muhammad Irfan [3], Wesam Salah Alaloul [1,*], Ahsen Maqsoom [4] and Maria Ghufran [5]

1 Department of Civil and Environmental Engineering, Universiti Teknologi PETRONAS, Bandar Seri Iskandar 32610, Perak, Malaysia; ali.musarat@utp.edu.my
2 Offshore Engineering Centre, Institute of Autonomous System, Universiti Teknologi PETRONAS, Bandar Seri Iskandar 32610, Perak, Malaysia
3 Civil Engineering Department, HITEC University, Taxila 47080, Pakistan; irfan7235@yahoo.com
4 Department of Civil Engineering, COMSATS University Islamabad Wah Campus, Wah Cantt 47040, Pakistan; ahsen.maqsoom@ciitwah.edu.pk
5 Department of Construction Engineering and Management, National University of Sciences and Technology (N.U.S.T.), Islamabad 44000, Pakistan; mghufran.cem17nit@student.nust.edu.pk
* Correspondence: wesam.alaloul@utp.edu.my

Abstract: The growing concept of Industry 5.0 (IR 5.0) has enhanced the study horizon of the technology-centered Industry 4.0 (IR 4.0) to an intelligent and balanced socioeconomic change powered mutually by people and technologies. The role of humans in the technological revolution is largely focused on IR 5.0, which is already a future trend. IR 4.0's cyber–physical systems revolution has evolved into IR 5.0, or in other words, from machine-to-machine integration to human-to-machine integration, which is radically altering how people live, work, and interact with one another. Therefore, the current study aims to comprehensively review transformation through industrial revolutions and provide a way forward in the construction industry with the incorporation of IR 5.0. This study has used a narrative-based research methodology in which multiple databases such as Scopus, Web of Sciences, Google Scholar, and Science Direct have been utilized for extracting articles related to the subject area of the current study. Moreover, through narrative-based methodology, which is a generic-based review technique, the information gathered from multiple sources has been summarized and synthesized. The findings of the review indicate that resilience, human-centricity, economic efficiency, and sustainable development are the key characteristics of IR 5.0. Moreover, the adoption of IR 5.0 in the construction industry also faces some major challenges such as a shortage of IR 5.0-related technical skills, investment-hesitancy among investors, security, and cultural concerns for human-to-machine integration, and an unavailability of data for effective decision-making for governments and stakeholders. The study results also highlight that with selective technology adoption, project teams embracing IR 5.0 for improved collaboration and coordination, more environmentally friendly technology adoption through human-to-machine collaboration, and stakeholders leveraging the power of human knowledge and innovative proficiency through machines, reforms can be brought into the construction industry through the incorporation of IR 5.0. It is also important to keep in mind that adopting IR 4.0 is still difficult in some areas and it may seem like achieving IR 5.0 will require years of effort and significant cultural change; however, it needs to be considered right away. The effects of disruptive technologies on Industry 4.0 are covered in several studies; however, IR 5.0 is a novel idea that is still in its early stages, thus its consequences have not been well examined in the construction industry. Therefore, the current study has expanded the body of knowledge on this important subject in detail and has comprehensively explained the transformation by providing a way forward for the adoption of IR 5.0 in the construction industry.

Keywords: revolution; IR 5.0; construction; sustainable development

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1. Introduction

The construction sector plays a pivotal role in a country's economy [1] as it accounts for about 6% of global gross domestic product (GDP) [2]. GDP is important in the market since it helps to balance various industries. Over time, the construction sector has encountered a massive transformation in the use of technology in projects [3]. The construction industry promotes the economic activities that encompass the entire construction process, from the production of raw construction materials and components, through the provision of professional solutions such as design and project management, to actual construction site activities [4,5].

Considering the significance of the construction sector, governmental stakeholders globally agree that boosting the infrastructure and real estate development industries, as well as providing affordable housing, is a common economic goal [6,7]. However, setting the wheel of the construction industry into motion faces numerous problems and obstacles. These include legal frameworks, organizational culture barriers, economic incentives, tax regimes, funding programs, procurement, supply chain tools and methods, and a system of checks and balances that must all be developed and made to function to cover both providers and purchasers. When a system is constructed from the ground up, the job becomes substantially more complex. That requires the utilization of more advanced tools, techniques, processes, and optimized coordination among teams, which is difficult to attain with obsolete methods [8,9].

Most governments are investing in research and development to promote environmentally friendly building practices. As a result, modernizing the construction sector will secure long-term developments. In terms of modernization prospects, the market size for Industry 4.0 was estimated to be USD 114.55 billion in 2021. Artificial intelligence, 3D printing, augmented and virtual reality, the Internet of Things (IoT), and blockchain are just a few examples of digital technologies that are disrupting every step of the value chain, including product design, supply chains, manufacturing techniques, and customer experiences. Strategic attempts by governments to digitize production processes across multiple industries were also supporting worldwide manufacturing industry giants like Germany, the U.S., France, and Japan. Since the inception of industrial revolutions, humans have consistently been evolving, i.e., the transformation from IR 1.0 to IR 5.0 [10,11].

Furthermore, it has long been argued that the construction sector is labor-intensive and sluggish in embracing new technologies. However, IR 5.0, which emphasizes the integration of humans with machines through automation, artificial intelligence (AI), and data analytics, is starting to take shape and has the potential to drastically change the way construction is realized. The current review study explores several topics within the context of transformational evolution through different industrial revolutions with the potential to revolutionize construction practices by raising standards for productivity, efficiency, and safety. The drive of this review is to examine the significance of this transformation in the context of different industrial revolutions, from IR 1.0 to IR 5.0, and provide a way forward for IR 5.0 adoption from the perspective of the construction industry. Perhaps this review study makes a persuasive case for the adoption of IR 5.0 in the construction sector as a way of advancing it into a more productive and technologically sophisticated era. Moreover, the current review will assist government stakeholders, key top management personnel, policymakers, and major players in the construction industry worldwide in addressing the industry's key challenges in the form of skilled workers in the face of a knowledge economy [12]. Furthermore, the concept of IR 5.0 is novel in the context of the construction industry and to expand and enrich the body of knowledge, a framework for decision-makers to successfully implement IR 5.0 in the construction industry has been proposed.

2. History of Industrial Revolutions

The Industrial Revolution (IR) was a significant turning point in history that had some sort of impact on practically every element of daily living [13]. The most significant outcome of the IR, according to some economists, was that this was the first time in history that the average person's standard of living in the West started to rise steadily. However, other economists believe that this advancement did not occur until the late nineteenth and early twentieth centuries [14]. Before the IR and the creation of the modern capitalist economy, GDP per capita remained mostly steady. However, with the IR, capitalist economies entered a period of per capita economic growth. Since the domestication of animals and plants, economic historians concur that the start of the IR was a significant event in human annals [15]. The exact beginning and conclusion of the IR, as well as the rate of societal and economic change, is still up for debate among historians [16]. T. S. Ashton claimed that the IR took place roughly between 1760 and 1830, while Eric Hobsbawm claimed that it started in Britain in the 1780s and was not felt until the 1830s or 1840s [17]. In the nineteenth century, mechanized textile production spread from the United Kingdom to continental Europe and the United States, with important textile, iron, and coal centers emerging in Belgium and the United States, and later textiles in France [18]. Figure 1 illustrates the transformation in different industrial revolutions.

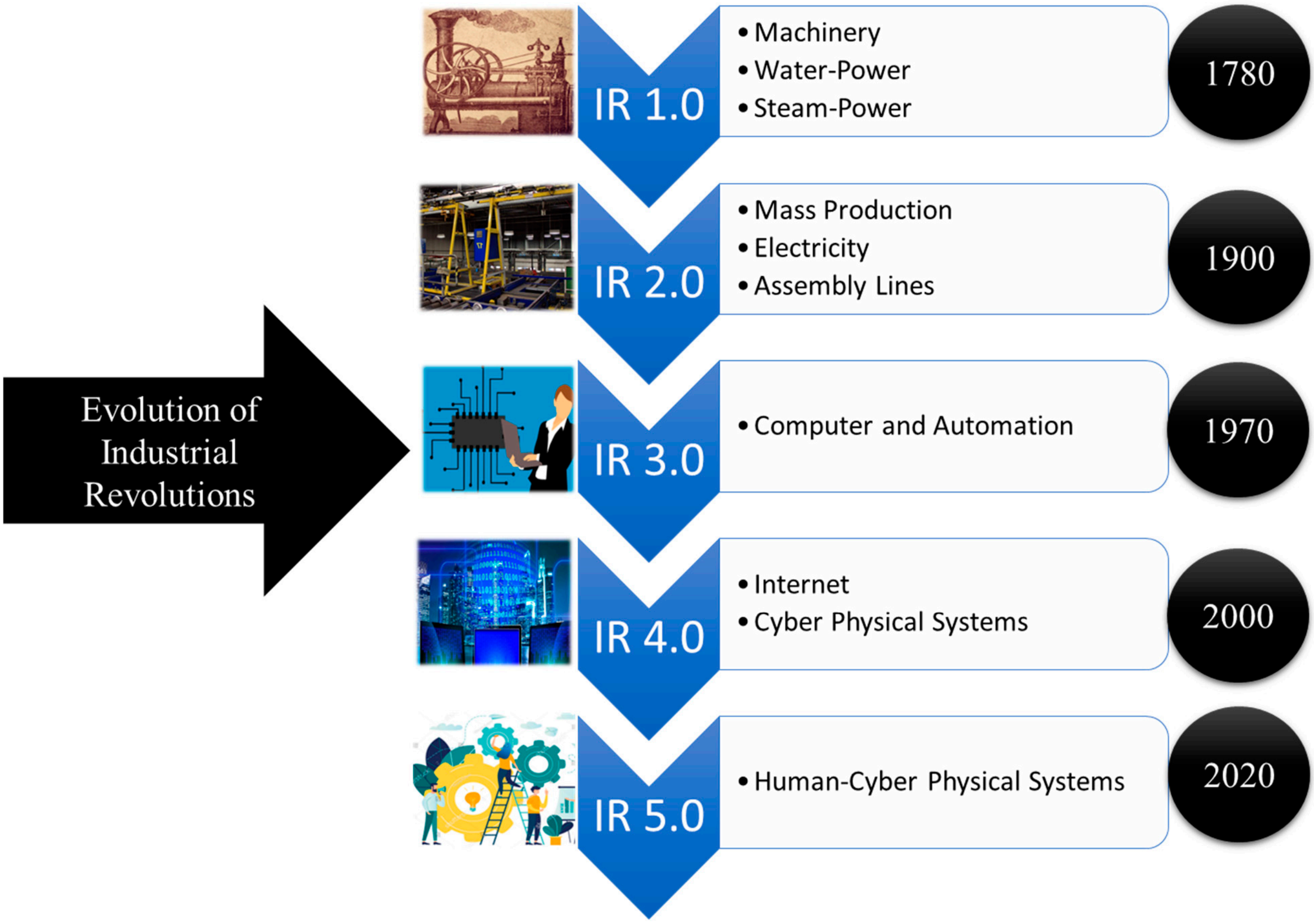

Figure 1. Industrial Revolution History.

2.1. Industrial Revolution 1.0

IR 1.0 had a significant impact on society, transforming the way goods were produced and leading to an increase in productivity and economic growth. However, it also led to social and environmental problems such as poor working conditions and pollution. The lessons learned from this period continue to shape the way we think about industrialization and its impact on society. The system improved [19]. Also, banking, and other financial systems improved to run the industries and business firms smoothly. Child and infant mortality rates decreased and fertility rates increased. As a result, population growth had changed intensely. This research concluded that IR 1.0 completely changed the history of human beings [20].

2.2. Industrial Revolution 2.0

From the late nineteenth century to the early twentieth century, the second IR, also known as the Technological Revolution, was a period of rapid scientific discovery, standardization, mass production, and industrialization. The first IR, which ended in the middle of the nineteenth century, was marked by a slowdown in significant inventions before the Second Industrial Revolution, which began in 1870 [21]. The development of the railway network allowed for the faster and cheaper transportation of goods, leading to the growth of international trade. The telegraph and telephone revolutionized communication, allowing for faster and more efficient communication between individuals and businesses. The assembly line, invented by Henry Ford, revolutionized the production of goods, allowing for the mass production of cars and other consumer goods at a much faster rate than before [22].

2.3. Industrial Revolution 3.0

Industry 3.0 utilized a newly recorded micro database for real advancement yield, the main impetuses, and mechanical interdependencies [23]. The combined forces of information technology derived the third IR, which has altered not just the way we work but also how we perceive the world and how we define it. A global village replaced society after the Third Industrial Revolution. People were empowered by technology and information providers to locate, retrieve, exchange, and use data in ways that improve their lives [24].

The word "technology" encompasses both dimensions of innovation. Due to China's rapid e-commerce growth, third-party payment technology has advanced significantly [20]. The payment business of the traditional financial industry, represented by commercial banks, is expanding in both breadth and depth thanks to this significant technological advancement, which was started by emerging internet enterprises. In the meantime, there is also a significant degree of substitution, competition, and crowding out among these banks in terms of the potential consumers, traditional intermediary firms, deposit and loan services, and basic payment and settlement activities of the traditional financial industry. However, an organization's technology transformation and acceptance are driven by entrepreneurial activities to develop new technologies. The value proposition that the company offers to the consumer has been impacted by technological progress in the financial industry. Understanding the sources of technical innovation is essential for maximizing investment and market potential. The market benefits from technological innovation, as well as inventors and early adopters [25].

2.4. Transformation of IR 3.0 to 4.0

The Third Industrial Revolution (TIR) was led by high-tech innovations in manufacturing, distribution, and energy factors. The TIR was global, but it was also local, giving rise to the term 'glocal'. The TIR was set to change the way we work, produce, and entertain. It fundamentally changed the way we plan and manage cities and regions [26]. IR 3.0 had a profound impact on the ICT, knowledge, defense, health, education, advanced manufacturing, financial, and administrative sectors [22].

2.5. Industrial Revolution 4.0

Industry 4.0 or IR 4.0 was established in Germany to modernize industrial manufacturing by utilizing emerging technologies and digitalization to their fullest extent [27]. Due to its capacity to increase operational effectiveness, efficiency, and the availability of new prospects, digitalization has become a widely accepted concept around the globe today [28]. A realistic and sustainable production system is the main focus of IR 4.0 [29]. The goal of Industry 4.0 is to digitalize industrial processes to establish a broad, adaptable network for production and services. The frameworks of IR 4.0, which are controlled by artificial intelligence, increase the usefulness of the human–machine interface [30]. The four main drivers underpinning Industry 4.0, which help transform manufacturing into a fully digital and intelligent process, are the Internet of Things (IoT), the Industrial Internet of Things (IIoT), cloud-based manufacturing, and smart manufacturing [31].

BIM (within the planning domain) can help overcome the digital gap that currently exists in the construction sector and continue to have an impact on upcoming building practices when combined with Industry 4.0 (the production domain) [32]. IR 4.0 technologies, as shown in Figure 2, provide better control and forecast of beneficial outcomes not only for business but also for society and the environment [33]. Industry 4.0 is a different field for stakeholders to adopt in the construction industry because they are not gaining a clear view of implementation [34], and its acceptance in the construction industry is challenging due to the advanced technology; therefore, stakeholders cannot invest. IR 4.0, also known as Industry 4.0, is the ongoing revolution that builds on the Digital Revolution. It is described by the incorporation of sophisticated technologies such as robotics, 3D printing, and blockchain into the production process [24].

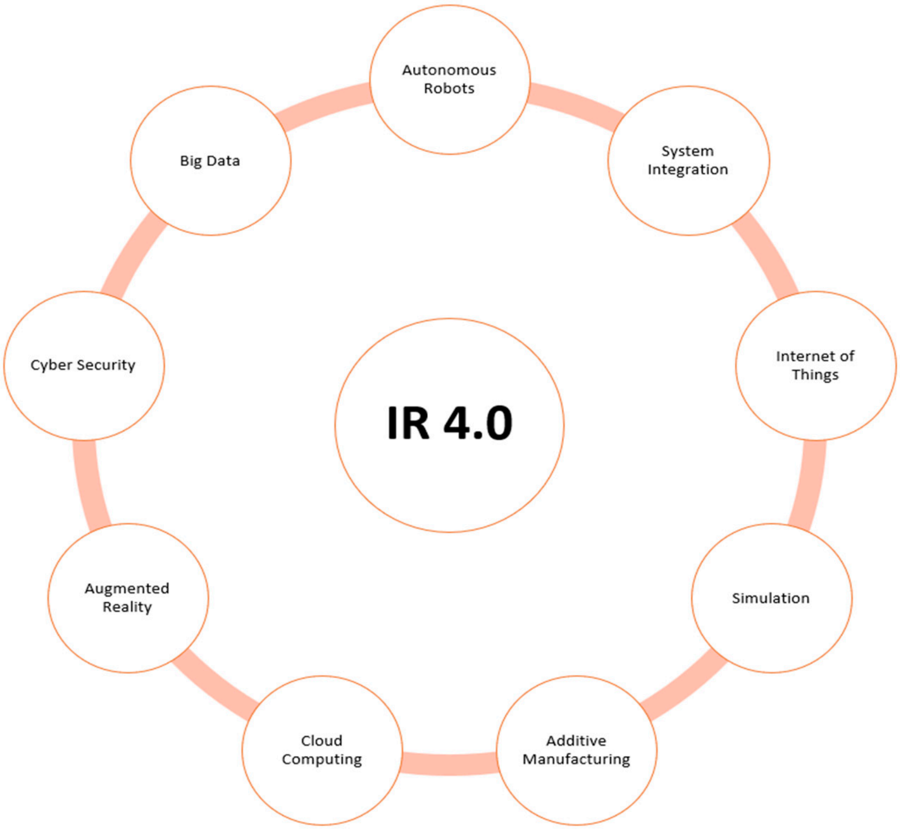

Figure 2. IR 4.0 Technologies.

As a result, IR 4.0 in the system for the construction sector concentrates on the shift from analog to digital [35] and, finally, the digital-to-physical transition to provide better coordination, planning, and execution of built environment infrastructure [36]. As previous scholars have stated, the idea of construction 4.0 is still evolving, and it is informed by its predecessors' conception of industry 4.0 [37]. As per [38], building a digital construction site with a variety of tools to track progress throughout a project's life cycle is the main goal of building 4.0. By using IR 4.0, the construction process as well as corporate and project frameworks would change, integrating the fragmented construction industry through cyber–physical systems [39] as shown in Figure 3.

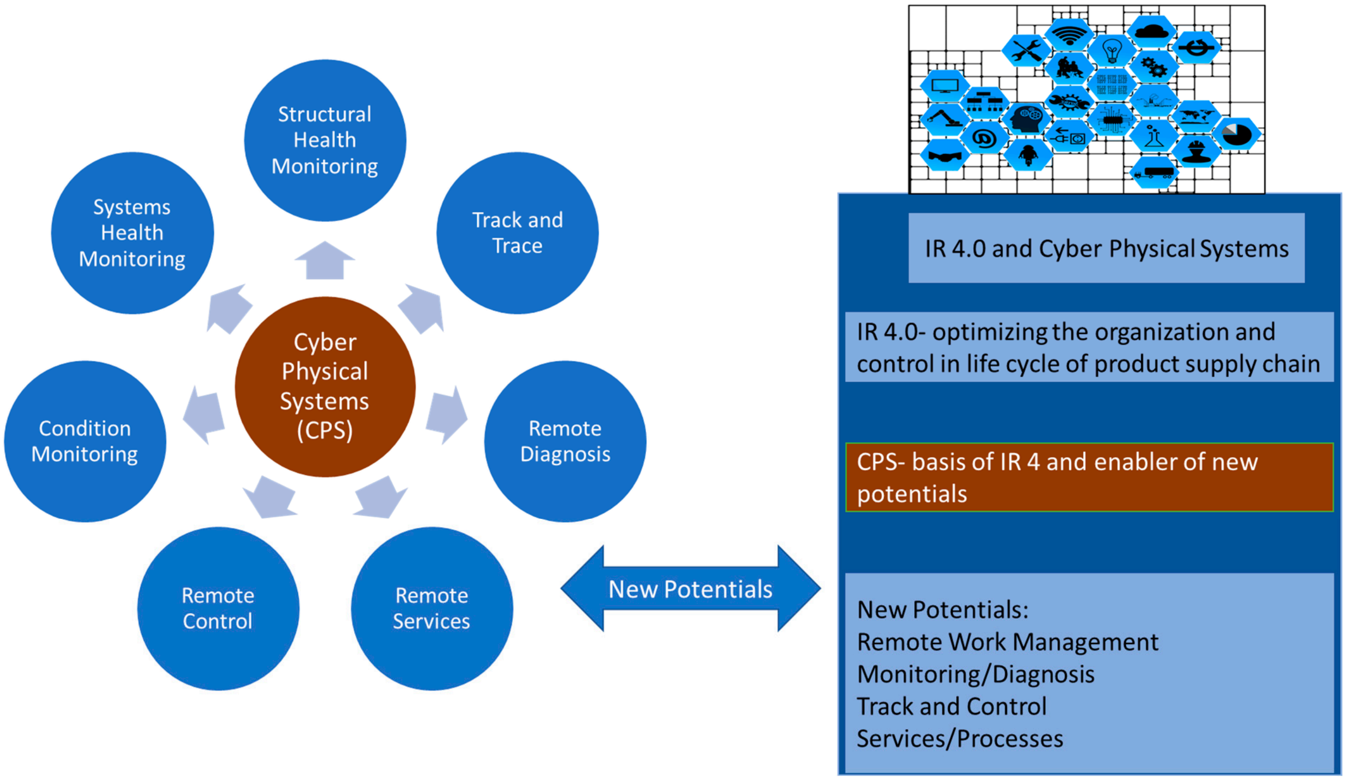

Figure 3. Cyber–Physical System in IR 4.0.

Construction is one of the most lucrative businesses, but it also has one of the lowest levels of R&D intensity [40]. Similarly, employment growth in the AEC has slowed over time despite nearly doubling in other industries [41]. In an era of Industry 4.0, the role of human resources is changing from machine operator to strategic decision-maker [42]. Robots assist humans with difficult, risky, and time-consuming activities, but for successful human–machine cooperation, humans must be effectively trained for these duties [36]. Construction is a labor-intensive industry; thus, there is a considerable possibility to boost productivity through technological innovation (such as the usage of robots), especially for potentially dangerous human labor. With the digital building platform, robots are only employed sparingly for tasks like 3D printing, wall construction, installing rebar, welding, using drones, etc. [43]. Industry 4.0 technologies are anticipated to have the biggest effects on businesses around the world [44]. Among these technologies, IoT and AI have the most drastic impacts of 72% and 68%, respectively [45].

2.6. Transformation of IR 4.0 to 5.0

To improve efficiency and productivity, IoT devices were created in Industry 4.0 and, as a result, increased efficiency and mass production and reduced costs [46]. Cooperation between humans and robots was challenging in Civilization 4.0 because knowledge and information exchange were insufficient and desired. The transformation from Industrial Revolution 4.0 to 5.0 is currently an ongoing process and is characterized by the integration of advanced technologies such as artificial intelligence, virtual and augmented reality, and advanced robotics [47]. The primary focus of Industrial Revolution 5.0 is on developing intelligent systems that can work collaboratively with humans and improve the efficiency of industrial processes. This includes the development of autonomous systems that can make decisions and take actions based on data analytics and machine learning algorithms.

One of the key areas of focus in Industrial Revolution 5.0 is the development of a more sustainable industrial system. This includes the use of renewable energy sources, the reduction of waste, and the development of closed-loop systems that minimize the use of resources. The use of advanced analytics and sensors is also critical in enabling real-time monitoring and decision-making to optimize resource utilization and reduce environmental impact. Another key aspect of Industrial Revolution 5.0 is the development of a more inclusive industrial system that is accessible to all. This includes the use of advanced technologies such as virtual and augmented reality to provide training and support to workers, as well as the development of adaptive manufacturing processes that can accommodate workers with different abilities [48].

Overall, the transformation from Industrial Revolution 4.0 to 5.0 represents a significant shift in the way industrial processes are designed and managed, with a greater focus on sustainability, inclusivity, and intelligent systems that work collaboratively with humans. This transformation is likely to bring about new opportunities and challenges, and organizations and individuals need to adapt to these changes to remain competitive and productive in the years to come. Industry 5.0, which incorporates the integration of human intelligence and cognitive computing, was developed to enhance the methods and efficiency of production [49]. With collaborative operations, Industry 5.0 aims to combine these cognitive computing capabilities with human intelligence and resourcefulness [50], as shown in Figure 4.

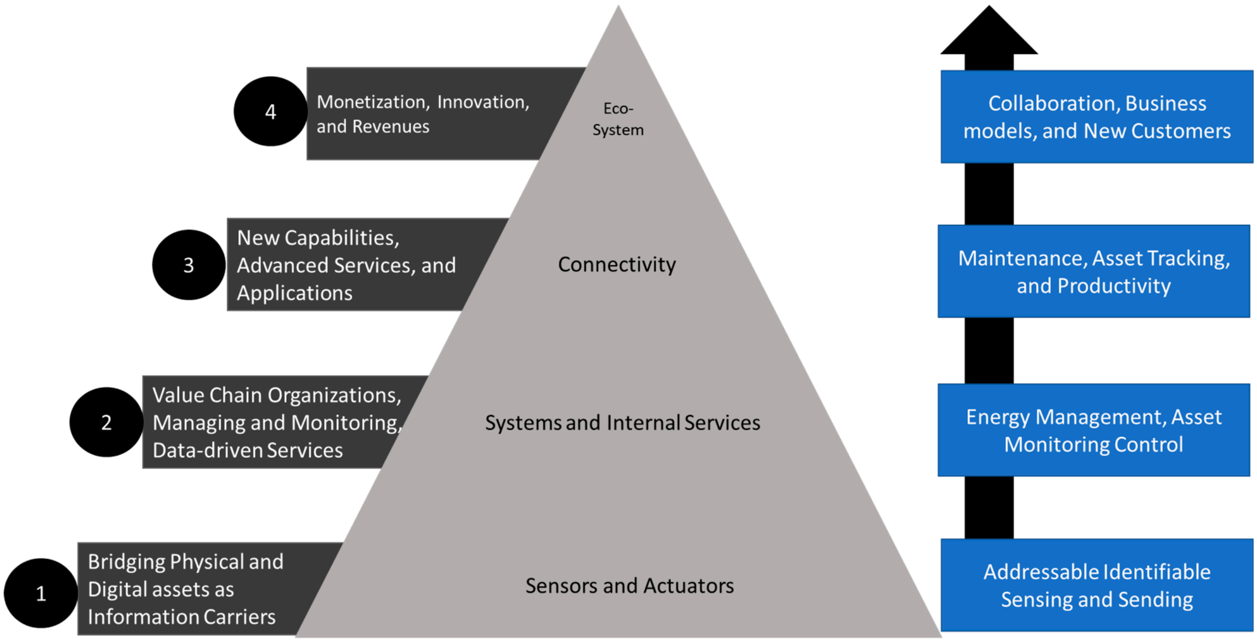

Figure 4. Industrial Transformations.

The fundamental tenet of "an orthogonal exit" is that events in hyper-connected networks have no bearing on the orthogonal departure pathways, hence the phrase "safe exit strategy". Such integration has a positive impact on Industry 5.0 as well, for instance: optimization of human efficiency and liberty of design [51]. Increasing the safety of the employees increases customer satisfaction and loyalty. In the construction industry, such integration of Industry 5.0 may alleviate barriers such as social polarization of unemployment, increased cyber security threats, huge amounts of investment, accountability, customer subjectivity, and monopoly [52]. The summary of these transformations is depicted in Figure 5.

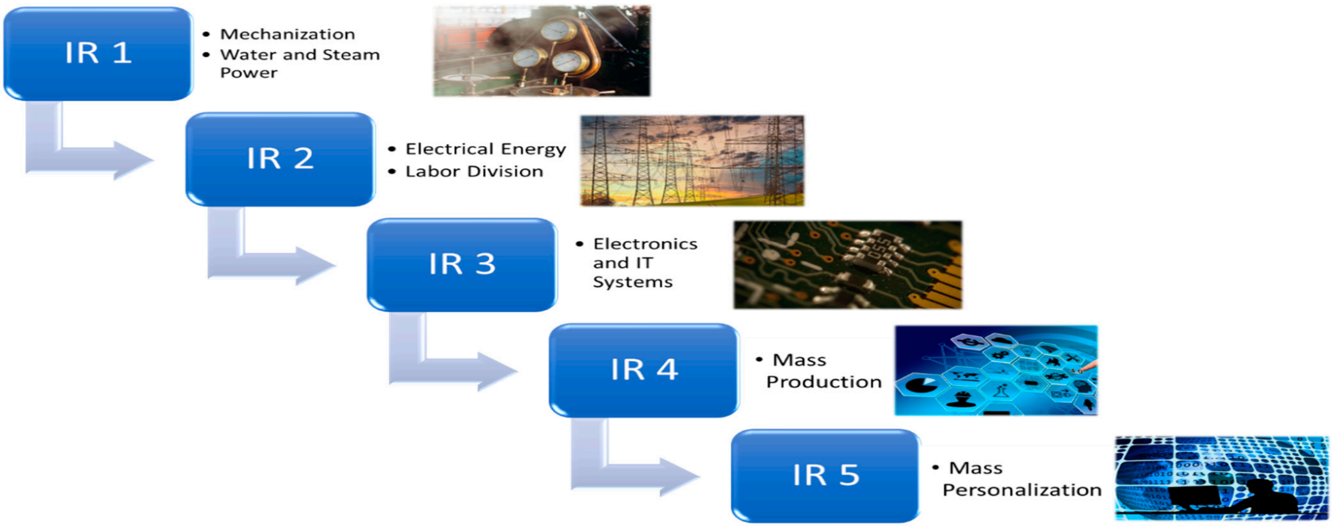

Figure 5. Summary of Industrial Revolution Transformation.

3. Industrial Revolution 5.0

The concept of the Fourth Industrial Revolution was unveiled at the Hannover Messe trade show in Germany in 2011, which is regarded as the year when Industry 4.0 first gained popularity. The initial vision of Industry 4.0 was also created largely for the German industrial automation and smart manufacturing markets, as well as for other nations that are members of the EU and are subject to EU legislation [53]. Industry 4.0 was also once thought to be primarily important to the European corporate climate and policies, even though it quickly became a global movement [54]. Whereas IR 5.0 compliments IR 4.0 philosophy by integrating humans with machines instead of replacing them. The transformational differences from IR 4.0 to IR 5.0 are depicted in Figure 6, while Figure 7 shows the technology enablers for IR 5.0.

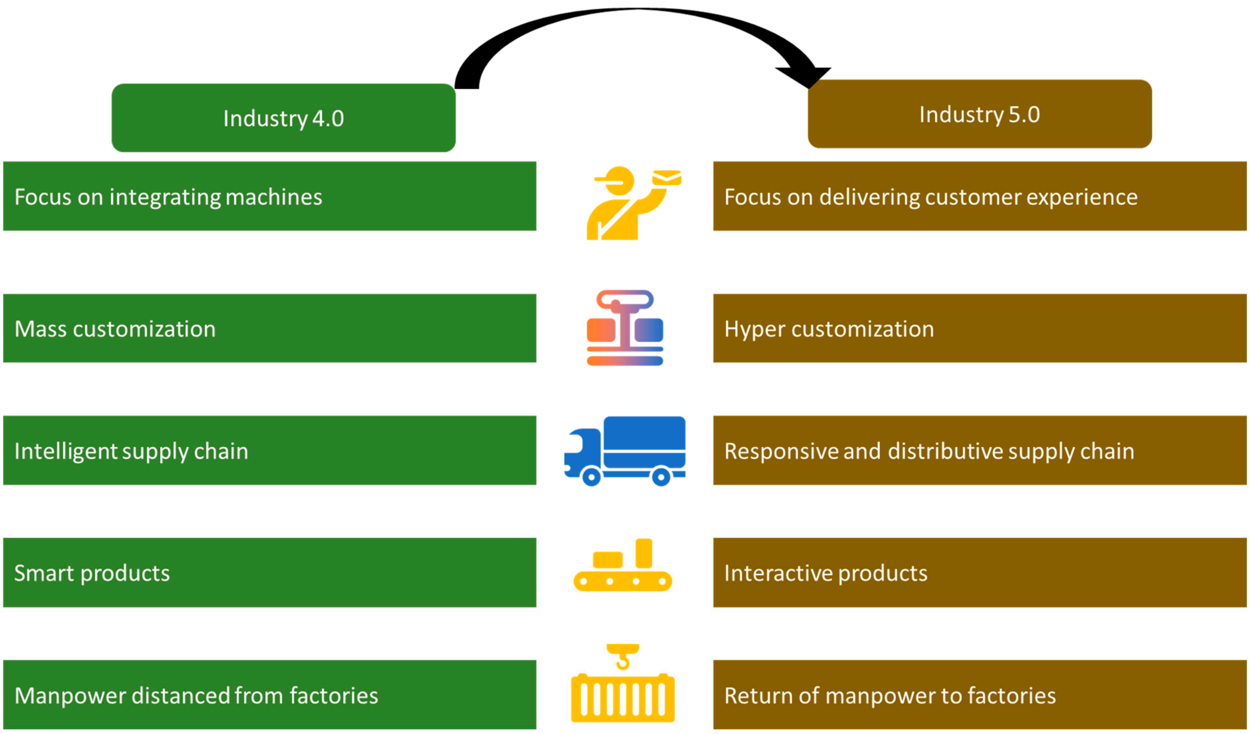

Figure 6. Transformation from IR 4.0 to IR 5.0.

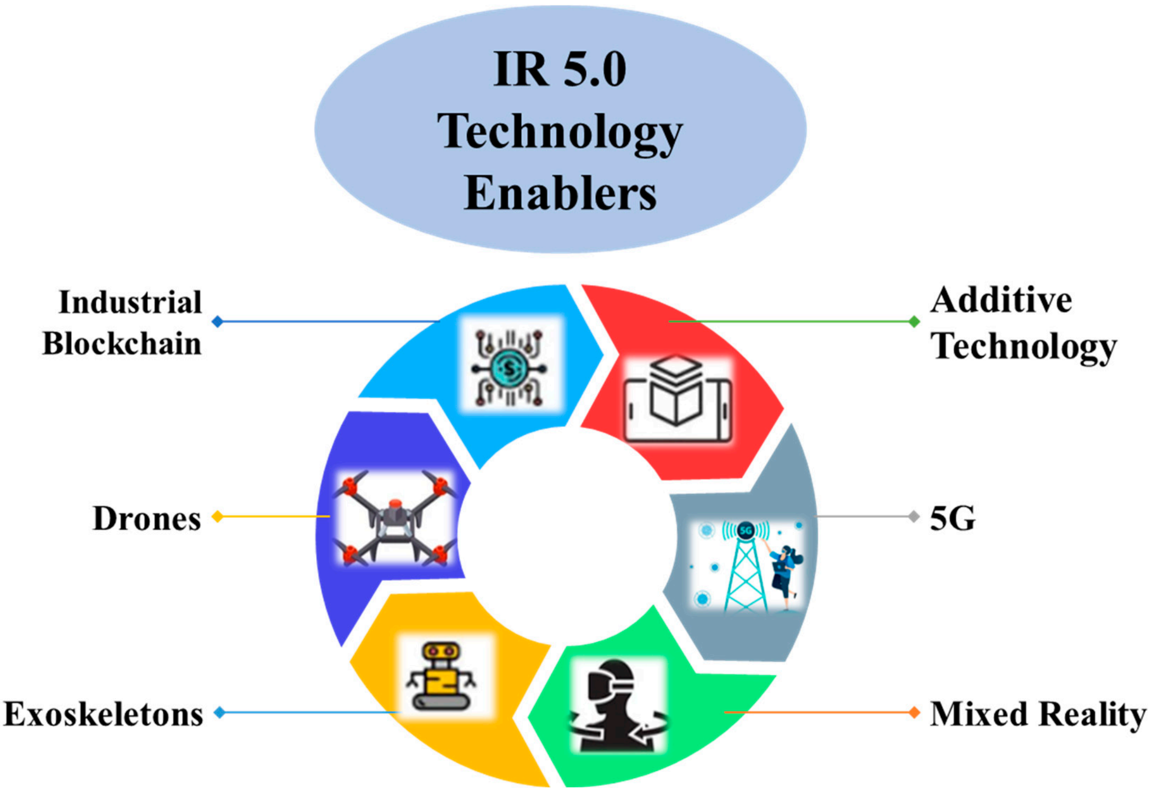

Figure 7. Technology Enablers for IR 5.0.

Industry 5.0 is a notion for the next stage of industrialization that is characterized by the return of labor to factories, distributed manufacturing, intelligent supply chains, and hyper-customization to constantly give a personalized consumer experience [55]. The key characteristics of IR 5.0 include:

3.1. Sustainability and Resiliency

In addition to empowering people, Industry 5.0 pays close attention to several resilience and sustainability-related issues. The impression is that Industry 5.0 proposes a framework that ought to strike a balance between the initial vision's competitiveness and business efficiency and a focus on sustainability, sensitivity to the environment, and deliberation on the processes of industrial automation on the environment [56]. Relying on adaptable, flexible, and agile technology is another aspect of Industry 5.0's push for resilience [57].

3.2. Collaboration between Machines and People

The emphasis is now on cooperative interactions between machines and humans, even though Industry 5.0 does not minimize the critical role that robots and automated equipment play in the new industrial revolution [58]. In addition to recognizing the well-known benefits and characteristics of robotic automation, such as the fact that these systems are more accurate, reliable, and productive than human workers, Industry 5.0 also recognizes all the drawbacks of excessive automation. For instance, the limited adaptability of highly automated solutions to shifting needs and specifications [58].

3.3. Enhancing Client Experience and Going All out on Personalization

The new idea is focused on offering better customer experiences—instead of just achieving high performance by linking machines and software when it comes to the consumer-facing side of industrial automation—products and services produced by Industry 5.0 solutions [59]. The capacity of businesses to provide clients with even better choices and product customization options while still reducing production costs due to robots, automation, and other cutting-edge technologies is what brings hyper customization and hyper-personalization to consumers [60].

3.4. Reasons to Adopt IR 5.0 Enabling Technologies

Most of the main technologies used in Industry 4.0 systems are also important mechanisms of the Industry 5.0 paradigm [61]. Industry 5.0's enabling technologies are typically broken down into six broad groups, as shown in Figure 7 [62]. The following are the key reasons to adopt IR 5.0 enabling technologies:

1. The use of augmented reality (AR) and virtual reality (VR) for inclusivity, training, and industrial testing;
2. Sophisticated safety gear and working tools that improve human skills through robotic tools and data communication;
3. Automatic speech and gesture detection:

Using AI and other cutting-edge technology to enhance human workers' cognitive capacities. Tracking gadgets to keep tabs on their physical and mental well-being.

4. Digital twins and simulations;
5. Robots that work together:

Since Industry 5.0 mainly relies on collaborative robots, or robots (also known as universal robots) that operate alongside humans rather than completely autonomous robotic solutions and industrial equipment, it is important to explore this area as well. In comparison to Industry 4.0, the significance of robots and all other types of human–machine interaction technologies and solutions is significantly greater in Industry 5.0 environments.

6. Human–machine integration:

Robots are made to interact directly with human workers, unlike industrial robots, which are often made to operate autonomously or as a part of a wider network of machines.

7. High adaptability:

The Industry 4.0 concepts' industrial robots are often created as specialized instruments that can perform one or more tasks. Without significant coding and engineering improvements, reading such machines is either impossible or highly challenging. On the other hand, robots are intended to be adaptable, simple-to-use machines that may be used for a variety of purposes.

8. Reduced prices and smaller sizes:

Robots are considerably more compact than standard Industry 4.0 industrial robotic systems. Additionally, because they are far more affordable to produce, this technology is more readily available to institutions and companies who do not have the funds to invest in expensive industrial machinery.

9. Easy to use and intuitive:

Additionally, collaborative robots are moving away from the excessive complexity of traditional industrial automation solutions. They are often made to be user-friendly and simple to program to make it easier to employ robots by human workers to increase productivity as well as to redeploy robots throughout a production area, for example. According to the Industry 5.0 paradigm, installing, programming, and calibrating collaborative robotic systems for each user's unique demands should not be prohibitively expensive.

10. Application to carry out a wider range of duties:

Robots are meant to be able to handle a variety of light activities as well, such as pick and place, material handling, and other jobs where they can help human employees but cannot fully replace humans, unlike industrial robots which are primarily made for heavy production.

11. Increased safety:

Additionally, robots are more frequently used for operations that have a high risk of accidents and injury for human workers. Utilizing them would enhance security, lessen accidents, and improve working conditions for human workers.

3.5. Transforming Construction Process with Construction 5.0 through IR 5.0

Construction 5.0 is an innovative approach that makes use of technology with the integration of human creativity to revolutionize industrial processes through the incorporation of the IR 5.0 concept [63]. To improve efficiency, productivity, effectiveness, and safety in construction projects, Construction 5.0, an enhanced iteration of conventional construction practices where technology compliments human creativity instead of replacing it, incorporates cutting-edge technology including artificial intelligence (AI), the Internet of Things (IoT), BIM, and robotics [64]. Stakeholders can significantly enhance project planning, implementation, and management by utilizing digital twins, unmanned aerial vehicles, smart sensors, and autonomous machines inside an interconnected system made possible by IR 5.0. Analysis of data in real time for better decision-making while eliminating mistakes and cost overruns is made possible by this transformational approach. Additionally, Construction 5.0 supports sustainability by encouraging eco-friendly products and procedures, minimizing waste production, and lowering carbon footprints during a project [65]. Construction professionals can unleash enormous value and foster innovation in a market environment that is becoming more competitive by embracing this paradigm change towards Construction 5.0 through IR 5.0.

By utilizing technology like drones, Internet of Things (IoT) sensors, and building information modeling (BIM), the construction industry may achieve human-to-machine integration. BIM makes team planning and design possible, and IoT sensors offer real-time information on tools, equipment, and worker safety [44]. Aerial photography from drones is available for site assessments and progress tracking. Through the continuous exchange of data between humans and machines, made possible by these technologies, the efficiency, safety, and decision-making of building projects are all improved. The construction industry has been gradually adopting technological advancements to increase efficiency, reduce costs, and improve sustainability. Some potential directions that the industry could take as part of a hypothetical Industrial Revolution 5.0 in construction might include:

(a) Using Advanced Automation and Robotics in Construction

The construction sector is being revolutionized by advanced automation and robotics, which increase productivity, security, and accuracy. These technologies include a wide range of applications, including robotic bricklaying, autonomous heavy machinery, and drones for site inspection [66]. Construction projects can be finished more rapidly, with lower labor costs, and with lessened human risk by automating repetitive operations and utilizing AI for project management. Additionally, these developments make it possible to build intricate structures that were previously thought to be unfeasible, ushering in a new era of eco-friendly and futuristic architecture [67]. The use of cutting-edge automation and robotics speeds up the construction process and provides better outcomes, making it a crucial part of the industry's continued development.

(b) 3D-Printed Building Modules and Additive Manufacturing

The construction industry has seen the emergence of ground-breaking technologies like 3D-printed building modules and additive manufacturing, which are fundamentally changing how we design and build structures [68]. These techniques enable the production of highly customized and complicated building components, from walls and façades to complete modules, by precisely stacking materials like concrete, plastic, or metal. This method not only vastly shortens building deadlines but also lowers labor and material costs, allowing architects and engineers to test out cutting-edge, sustainable solutions that were previously difficult to realize. Furthermore, 3D printing can be used to construct structures on-site quickly and efficiently in remote or disaster-stricken places [69]. The ability of these technologies to transform the construction sector and promote environmentally friendly building techniques is growing as they develop.

(c) Digital Twin and Building Information Modelling (BIM)

In the design and construction sectors, key advances include digital twins and building information modeling (BIM). Using digital twin technology, physical buildings can be digitally replicated in real time, enabling continuous monitoring and analysis throughout a building's lifetime. Conversely, BIM entails the development of a comprehensive 3D model of a construction project that includes information about its systems, materials, and components [70]. Together, these technologies give planners, designers, and contractors the ability to precisely optimize planning, design, and construction processes. Through continuous insights into a building's performance, digital twins enable predictive maintenance and increases in energy efficiency. BIM improves stakeholder coordination and collaboration, minimizing mistakes and delays. In the construction industry, they usher in a new era of data-driven decision-making, sustainability, and efficiency [71].

(d) Smart Materials and Sustainable Construction

Sustainable construction techniques are being advanced by smart materials. These cutting-edge materials have special qualities that react to outside stimuli, like temperature, light, or stress, allowing structures to adapt and perform at their best in the moment [72]. They contribute to sustainability by improving energy efficiency by using self-regulating insulation or photovoltaic materials to capture solar energy. In addition, replacement can increase a structure's longevity and durability, reducing the need for routine upkeep and replacement, and lowering resource consumption and waste production. The modern search for sustainable and resilient construction solutions is perfectly aligned with the incorporation of smart materials into construction, which not only make buildings more environmentally friendly but also improve occupant comfort and overall operating efficiency [73].

(e) Renewable Energy Integration

One of the most important steps towards a sustainable and environmentally responsible future is the incorporation of renewable energy resources into our energy infrastructure. The utilization of clean, nearly endless renewable energy sources, such as solar, wind, hydro, and geothermal energy, can drastically lower greenhouse gas emissions and our reliance on fossil fuels. We can generate electricity effectively and reliably while reducing the negative consequences of climate change by integrating these sources into our energy systems and infrastructure [74]. Additionally, improvements in grid management systems and energy storage technology are making it easier to integrate renewable energy, guaranteeing a reliable and resilient energy supply for communities and companies around the world. In addition to addressing the urgent need for carbon reduction, this shift towards renewable energy also promotes economic growth [67].

(f) IoT and Connectivity

Connectivity and the Internet of Things (IoT) have ushered in a revolutionary era across many industries, providing previously unattainable levels of data-driven insights and automation. The Internet of Things (IoT) is a large network of networked gadgets and sensors that can gather, distribute, and analyze data instantly. IoT-enabled devices are improving efficiency, productivity, and decision-making across a variety of industries, from manufacturing and healthcare to transportation and smart cities [75]. IoT provides proactive maintenance, remote monitoring, and better resource management by facilitating a constant flow of information. Additionally, convenience and personalization are improved by the incorporation of IoT into daily life through wearable technology and smart houses. The potential for IoT and connectivity to create a more effective, sustainable, and integrated future continues to expand as our world becomes more networked, with ripple effects.

(g) AI and Predictive Analytics

By utilizing the power of data to make proactive, data-driven decisions, AI and predictive analytics are revolutionizing numerous industries. Artificial intelligence (AI) systems can analyze large datasets, spot patterns, and predict future trends and outcomes thanks to sophisticated machine learning algorithms [76]. Because it makes it possible to assess risk, detect fraud, provide individualized advice, and estimate demand, this technology is invaluable in fields including banking, healthcare, marketing, and supply chain management. AI increases productivity and accuracy by automating difficult data analysis and prediction activities, which ultimately spurs innovation and competition. As AI and predictive analytics advance, they could change business models, streamline processes, and influence how decisions are made in the future for a variety of applications [77].

(h) Modular Off-Site Construction

Modular off-site construction, often referred to as off-site or prefabricated construction, is a revolutionary approach to building that involves manufacturing building components or modules in a controlled factory environment and then transporting and assembling them on-site. This method offers numerous advantages, including reduced construction time, increased cost-effectiveness, and improved quality control. It minimizes weather-related delays and site disruptions, making it especially appealing for projects with tight schedules or challenging environmental conditions [78]. Additionally, modular construction promotes sustainability by reducing material waste and energy consumption during construction. Its versatility allows for innovative architectural designs and can be applied across various building types, from residential and commercial structures to healthcare facilities and educational institutions. In an era of increasing demand for efficient, eco-friendly, and adaptable construction solutions, modular off-site construction is poised to play a pivotal role in shaping the future of the industry.

3.6. Role of IR 5.0 in the Manufacturing Industry

Industry 5.0, a wave of cognitive computing infrastructure and apps that are redefining how commodities are created, is transforming the manufacturing sector [79]. Process manufacturing will experience yet another upheaval as Industry 5.0, a new wave of cognitive computing applications and infrastructure, transforms the production of chemicals, pharmaceuticals, and biotechnology products. It is critical to comprehend the initiative's definition and all its ramifications. The first aspect of Industry 5.0 is how people will collaborate with robots and intelligent machinery [56]. Of course, encouraging individuals in manufacturing plants to share information is a necessary part of shift-to-shift communication. However, in Industry 5.0, robots will be assisting humans in their work by using the IoT and big data [80]. The industry should emphasize the requirement for a personal human touch more than Industry 4.0 pillars of productivity and automation [81].

Robots have regularly performed physically demanding, dull, or dangerous work like welding in auto plants or loading and unloading heavy objects from trucks in warehouses. Industry 5.0 makes strides beyond Industry 4.0 that will enable collaborative operations that combine cognitive computer skills with human intelligence and resourcefulness. Industry 4.0 introduced smarter and more connected robots to the workplace [82]. Industry 5.0 will soon provide the acceptability and acknowledgment required to integrate people's creative and cognitive abilities with the speed and accuracy of the technology. As a result, the system will be stronger and more competitive. People will have more freedom to use their innate cognitive abilities to contribute even more value to the plant floor because of coexistence, which will open a wide range of exploratory prospects, including novel and interesting employment opportunities [83]. Even the creation of new social contracts and improved communication on the production floor are possible outcomes of Industry 5.0. There will be more opportunities for human-to-human collaboration in more significant ways, invoking information that will promote resilience and responsibility, and ensure compliance, in addition to communication between humans and their robots. Human-led activities, for instance, can react to unfavorable situations or assist in reducing the risk from large-scale catastrophes like the pandemic. Let's face it, when all is said and done, people, not machines, are in charge.

The question is not whether a company can gain from having humans collaborate with robots, but rather how they might use AI-enabled tools to achieve the best results from human–machine interactions. Businesses that leverage technology to enable employees to harness their innate skills and abilities to boost productivity will succeed [84]. Industry 5.0 is expected to provide a situation where people and robots may interact effectively. This will make it possible to address the problems of complicated production in the future, including increased customizations through automated manufacturing processes that are optimized, which will call for a lot of cooperation [85]. All plant functions will benefit from increased transparency, dependability, and visibility because of which teams will be better able to interact and provide the best results. Manufacturing companies may increase productivity, cost-effectiveness, quality, and safety thanks to people-centric technologies [86]. All in all, Industry 5.0 is a concept that is starting to gain traction and that places the Industrial Revolution's power to positively affect society at its core.

3.7. Role of IR 5.0 in the Construction Industry

3.7.1. Executing a Project with a Human Focus

Industrial projects are very intricate. When automation systems are fully implemented, human ingenuity can be repressed according to the mass automation paradigm. Incremental improvements are frequently impossible once the system achieves a steady state. Changing an operating system frequently calls for extensive design, new hardware or software, and financial expenditure [87]. As a result, innovation may be discouraged or downright forbidden for a while (until capital expenditures can be recovered). Contrarily, using humans in automated operations can be discouraged, mostly because it requires investing in costly software. Think about the implementation of an automated pipe drafting system that chooses the best piping routing for a designer, as an example. Even if the designer does not think the routing is ideal, if the designer is forced to accept it because of an overreliance on technology, we can perceive the gap between people and technology [88].

People are empowered by Industry 5.0. To spur innovation and industrial progress, it blends its creative potential with cutting-edge technology. Furthermore, with capital projects continuing to grow in complexity, this innovation is more important than ever. Digital literacy is crucial because human capital is highly valued in Industry 5.0 [20]. Programs for developing technical skills and digital literacy will both receive increased funding from project teams. To decrease costs and shorten deployment schedules, many teams are currently choosing to slash training expenses. This will no longer be a workable budgeting choice in Industry 5.0 because human innovation is essential to success [89]. Greater inventiveness in the initial stages of project planning will result from Industry 5.0. To enhance overall project delivery models and construction execution tactics, innovative ideas will be sought after and fostered. To guarantee that important project goals are created and met, engineering design programs will incorporate strategic planning and tactical planning sessions for constructability and sustainability [90].

Transparency in material sourcing and production processes, near real-time visibility of fabrication status, and a material tracking protocol, are more in line with what we have come to expect from online purchasing thanks to shipping and logistics data (continuous alerts and real-time delivery tracking). Engagement and empowerment using cutting-edge technology will significantly increase construction efficiency instead of a persistent concentration on highly automated operations. Construction sites are not manufacturing facilities; the success of a project depends just as much on good manufacturing and design as it does on inventive field execution and dynamic planning protocols. Furthermore, if the success of any new project is solely determined by the reduction in time spent using the tools (a poor efficiency model), the operational model will be swiftly superseded by the 5.0 revolution. Instead of a constant race to automate, construction innovation and originality will become fundamental drivers of Industry 5.0 models [91]. In a 5.0 model, measuring productive time is outcome-oriented rather than reliant on how much time a craft professional spends holding a wrench.

3.7.2. Adaptive to Collaboration

Unlike Industry 4.0, which encouraged teams to work in partially connected virtual project delivery models, Industry 5.0 encourages teams to work together again in co-located or immersive virtual environments rather than in siloed organizations. Teamwork is essential, and both in-person and virtual teams need to be able to communicate constantly [92]. To facilitate stakeholder involvement in this new paradigm, even between contractors who might typically be viewed as rivals, virtual collabs that bring together stakeholders from engineering, sourcing, construction, commissioning, and project management teams are essential. Collabs move rapidly, collaborate, make comprehensive decisions, and have a beneficial impact on project trajectories thanks to advanced data and technology use. Being adaptive to collaboration also benefits organizations. In today's fast-paced and competitive business environment, organizations need to be able to respond quickly and effectively to changing circumstances [83]. This requires a high degree of collaboration and adaptability, as teams need to be able to work together to achieve a common goal, even in the face of unexpected challenges or obstacles. Organizations that promote collaboration and adaptability are more likely to succeed, as they are better able to leverage the collective skills and knowledge of their employees to achieve their objectives [93].

3.7.3. The Tech That Gives Power

Industry 5.0 wants systems to be resilient rather than stable. As more black swan events (climate- or health-related, and political) take place and disrupt regular project operations, technology systems and solutions that favor stability over resilience will depreciate [94]. In this scenario, technology that promotes system resilience will be increasingly common, and project teams will place less emphasis on mass-automation solutions (automated and heavily scripted process enablers). Rapidly deployable software with adaptable workflow choices will therefore be favored in the industrial project arena over extremely inflexible, process-driven technologies [95]. Digital twins are essential to initiatives that use 5.0. Being a hub for knowledge, they link people and technology in ways that foster creativity. The democratization of data will enable project teams, including engineers, project managers, construction team members, and operations staff, to collaborate easily within digital twins. In Industry 5.0, edge computing will become increasingly prevalent to meet the demands of project teams for large-scale data collecting and processing [96]. The adoption of machine learning and AI will grow, and teams will manage more data instead of just big data. Systems thinking will be crucial for developing and deploying cyber–physical systems as well as for designing and operationalizing systems and solutions [97]. Cobots will become more commonplace. Cobots operate and interact directly with humans, unlike robots, which are physically separated from their human counterparts [59]. These increase work productivity while enabling both mass manufacturing and mass personalization of work outputs. In fabrication facilities, on-site laydowns, and support spaces like tool cribs and field offices, cobots will be commonplace [98].

3.7.4. Focus on Sustainability

Projects under Industry 5.0 are heavily focused on the environment. Any project's success depends on sustainability, which should not just be a top concern. Teams in Industry 5.0 assess the environmental effects of their actions and collaborate to reduce environmental risks [89]. They also place a strong emphasis on resource efficiency and design, create project plans that reduce jarring changes in resource requirements, incorporate sustainable production techniques, and factor in embodied carbon when setting design parameters. Teams working on Industry 5.0 projects see sustainability as a responsibility, and they genuinely care about producing results that have a beneficial influence on the built and social surroundings [99].

3.8. Barriers and Challenges in the Adoption of IR 5.0

Industry 5.0 advances now face challenges that must be overcome for a company to succeed. The following are the main obstacles to the implementation of Industry 5.0:

1. Using state-of-the-art technology requires more time and effort from human workers. In addition to specialized software-connected factories, Industry 5.0 demands the utilization of collaborative robotics, artificial intelligence, real-time data, and the Internet of Things [58].
2. Investments in cutting-edge technologies are necessary. Adopting Industry 5.0 is expensive since smart machines and highly skilled personnel are required to increase production and efficiency [59].
3. To communicate with a variety of devices and defend against potential quantum computing applications when deploying IoT nodes, authentication has been utilized in the industry. Since ICT systems lie at the heart of Industry 5.0 applications, strict security standards are required to prevent security risks [50].
4. Currently, the economic impacts of Industry 5.0 in the construction industry have not been researched comprehensively and coverage of the literature on this aspect is missing. The main reason lies in the fact that it is a novel concept and has not been accepted widely by major stakeholders. The economic impacts will be studied once it is implemented globally, which is currently a piece missing from this puzzle.

3.9. Reforms with IR 5.0 in the Construction Industry

The Fifth Industrial Revolution has already begun and, because of the overlap with the Fourth Industrial Revolution, the transition will take longer and require more conscious effort to accept than the changes companies had to make during previous industrial revolutions as shown in Table 1. Due to the exponential growth of technological capability, the time between industrial revolutions has historically gotten shorter; yet, this is the first time that an industrial revolution has overlapped in recorded history. For many, embarking on this 5.0 journey entails improving upon or extending the present 4.0 experience [98]. It will result in a full reframing of operating strategies for some. It is difficult to move from 4.0 to 5.0. However, this transition is merely another step along the path for engineering and construction teams that embrace the potential for positive change. Forward-thinking teams are in a great position to start moving toward version 5.0 right away for an unavoidable revolution [100].

Table 1. Case Studies (Practical Implementation).

Sr.No	Case Study	IR 4.0 Incorporation	Improvement through IR 5.0	Reference
1	**Apis or 3D-Printed House in Russia** A modern method of building is the integration of the IR 4.0 construction protocol into the Russian Apis or 3D-Printed House project. This protocol uses Industry 4.0 technologies to automate and optimize the building of homes, including 3D printing, IoT sensors, advanced robotics, and data analytics. The result is a building process that is more effective and economical, wastes less labor and materials, and offers more design flexibility. This protocol offers a substantial advance in modernizing the building sector and addressing housing difficulties with creative, sustainable solutions by merging digital design, real-time monitoring, and automated construction technologies.	3D printing, IoT sensors, Advanced Robotics, and Data Analytics	Utilization of interactive products and hyper-customization could further enhance the construction process and customer experiences.	[101]

Table 1. *Cont.*

Sr.No	Case Study	IR 4.0 Incorporation	Improvement through IR 5.0	Reference
2	**TECLA house construction in Italy** The implementation of cutting-edge Industry 4.0 technology in the construction industry is demonstrated by the IR 4.0 construction protocol used on the TECLA house construction project in Italy. This project embodies efficiency and sustainability because it uses a distinctive 3D printing technique and materials that are acquired locally. Real-time monitoring using IoT sensors and data analytics ensures accuracy and quality control during the construction process. The TECLA project shows how cutting-edge robotics, automation, and digital design have the potential to revolutionize the building sector and make it possible to build eco-friendly, individualized, and affordable housing solutions that meet contemporary needs.	3D printing and IoT sensors	With the incorporation of a responsive and distributive supply chain, resource efficacy can be improved. Moreover, through human–machine interactions, the creativity of humans and the efficiency of machines can further improve construction operations.	[102]
3	**Shanghai Chenshan Botanical Garden in China** Technology like IoT sensors for plant monitoring, data analytics for resource optimization, and automation for maintenance and guest services might all be used in a botanical garden to implement Industry 4.0 principles.	IoT sensors, Data Analytics, and Automation	Instead of completely employing machines, humans working with intelligent devices and robots should be adopted. It is about using cutting-edge technology like the Internet of Things (IoT) and big data to enable robots to assist people in working more effectively and quickly.	[103]

People are given more authority by Industry 5.0, which uses the resources at hand to produce more significant value. Industry 5.0 offers a holistic project delivery paradigm that incorporates key issues of concern to present to future project leaders, which is a significant advance above IR 4.0. Although the evolution to IR 5.0 is unavoidable, there are certain significant advantages that CEOs should consider when determining whether to hasten the transition inside their businesses and project teams:

1. Teams that are empowered by Industry 5.0 leverage human knowledge and innovation more frequently;
2. Using technology more selectively, teams switch from mass automation to flexible solutions that can automate, or mass customize, enabling performance at scale under a variety of scenarios;
3. Improved cooperation—teams use virtual co-location technology and seamless communication channels to work more effectively together;
4. More environmentally friendly construction techniques—project teams place a greater emphasis on sustainability, incorporating environmental and social effects into planning and decision-making.

4. Conceptual Framework

Human–economy-centric, sustainable, and resilient development are the three leading stakes of Industry 5.0 as proposed in the framework shown in Figure 8. Industry 4.0

was primarily focused on using technology to remove humans from the manufacturing process and only entrust them with supervision and control tasks, which caused production workers to perceive increasing automation and digitalization as a severe danger. The core of Industry 5.0 is the interaction of three sectors: technological, social, and ecological. Industry 5.0 emphasizes the importance of technology in driving economic growth (business). However, achieving corporate goals also involves achieving social goals both inside and outside of the workplace, such as those related to human–machine relations (social and ecological responsibility). System designers must create projects in Industry 5.0 with a "human-centered" rather than a "technology-centered" mindset. The potential for complex judgments to be made outside of the control of humans raises ethical concerns regarding the repercussions of the development of artificial intelligence. For human values and ethical considerations to be addressed as design needs rather than expenses in freshly created cyber–physical systems, it is necessary to analyze them in advance.

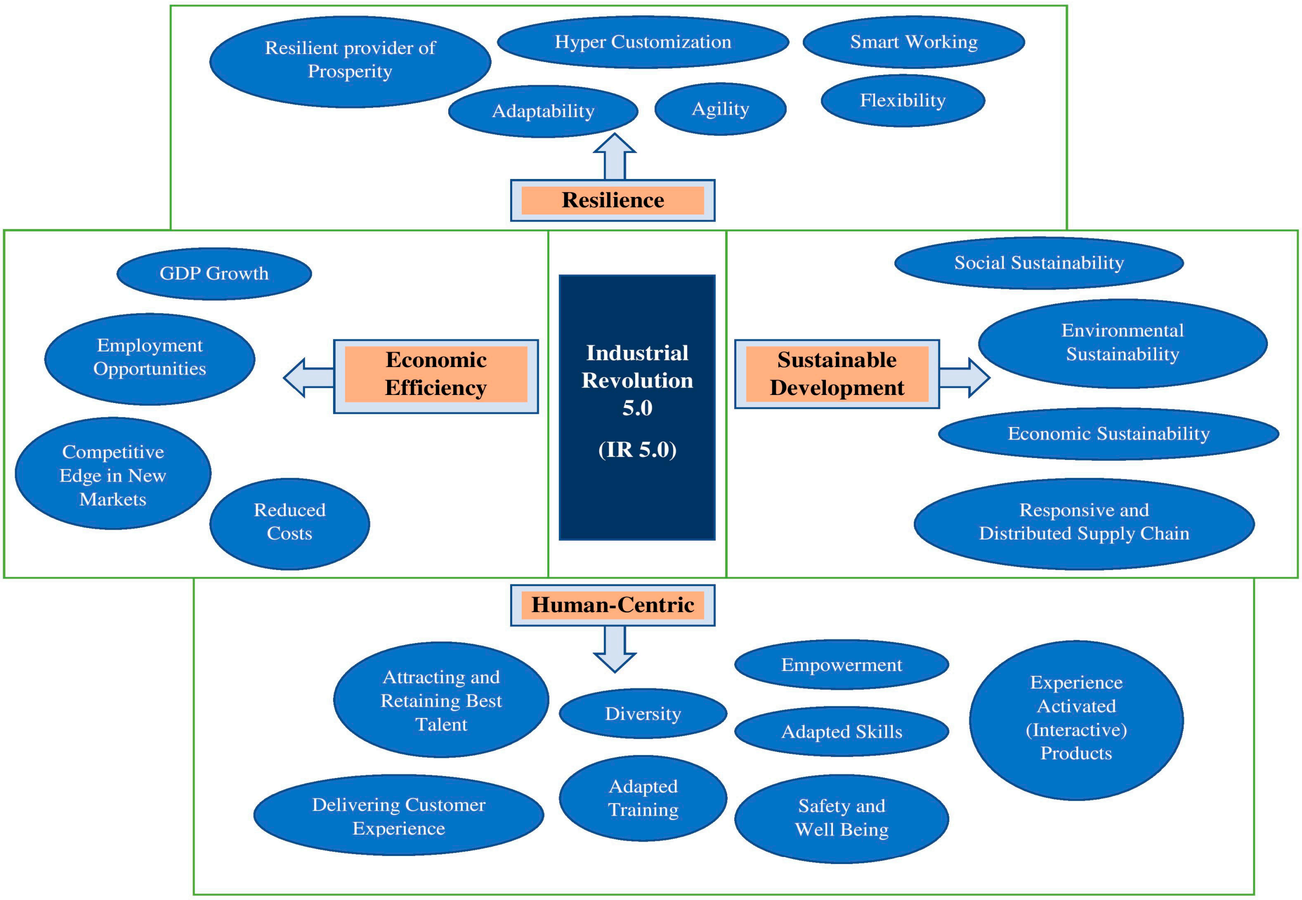

Figure 8. Framework for IR 5.0 Adoption.

Industrial Revolution 5.0 technologies are essential for increasing productivity and competitiveness in the manufacturing and construction sector. An illustration of this is the use of the Seru production system, a lean manufacturing strategy created in Japan. To optimize its production processes, Seru mainly relies on automation, IoT sensors, and data analytics. These technologies enable manufacturers to create highly adaptable and effective manufacturing cells where employees and machines work together seamlessly. Real-time data collected by sensors enables predictive maintenance and quick problem solutions. This improves product quality while simultaneously decreasing downtime. Manufacturing is now able to switch from mass production to highly customized and adaptable production methods, satisfying changing market demands while remaining cost-effective.

4.1. IR 5.0 and Sustainability in Construction

The Fifth Industrial Revolution, which will emphasize collaborative interaction between machines and people, is now upon us. Professionals are free to provide clients with value-added tasks because of personalization and the incorporation of collaborative robots. This most recent iteration includes greater resilience, a human-centric strategy, and an emphasis on sustainability in addition to manufacturing and construction methods. By actively pursuing initiatives to bring about change, Industry 5.0 expands sustainability beyond merely reducing, minimizing, or adapting against climate impact. This objective sometimes referred to as "Net Positive," strives to improve the planet by having businesses contribute to the solution rather than contributing to the problem or merely paying lip-service to objectives of sustainability through greenwashing. IR 5.0 has the potential to profoundly impact the economy. The first way that IR 5.0 can increase production is by streamlining procedures and lowering human error rates using robotic and automated equipment. This may lead to reduced project costs and quicker project completion schedules. Furthermore, AI-powered analytics facilitate better decision-making by offering immediate information on the efficiency of projects, the distribution of resources, and risk control. Additionally, the adoption of these technologies opens up opportunities for workers to upgrade their skills and acquire the new technical abilities needed to operate alongside sophisticated systems. It is important to understand that IR 5.0 encourages job growth in industries like software development and maintenance of these complex systems, despite concerns about job displacement brought on by automation.

Consequently, construction operations can be improved to cut down on waste, energy use, and environmental effects with the use of IR 5.0 technology. AI-enabled systems may analyze data and identify possible bottlenecks or defects in designs, maximizing resource efficiency and reducing material waste. Real-time monitoring of energy use and atmospheric conditions on building sites is also made possible by IoT devices, improving resource control and efficiency. Robotics is essential in automating monotonous or dangerous building operations for workers while assuring precision and minimizing human error. Industry experts may help create a greener infrastructure that supports sustainable development and a sustainable future by incorporating IR 5.0 concepts in construction practices with a sustainability lens.

4.1.1. Sustainable Development

By encouraging eco-friendly and effective practices, Industrial Revolution 5.0 has the potential to greatly contribute to sustainable development. Industries may cut back on resource use, cut emissions, and improve supply chains by integrating technology like AI, IoT, and renewable energy. Smart grids, for instance, can improve energy efficiency, and AI-driven logistics can reduce carbon footprints associated with transportation. Additionally, IR 5.0's emphasis on circular economies and sustainable materials promotes responsible resource management and lower waste production, bringing industrial advancement and long-term environmental and social sustainability goals into alignment.

4.1.2. Human-Centric

Strong emphasis is placed on human-centric design and technologies in Industrial Revolution 5.0. It combines automation, robotics, and AI to improve workers' productivity and well-being. For instance, wearable technology and exoskeletons can improve safety and comfort in physically demanding industries, while AI-driven systems can assist people with repetitive activities, decreasing workload and errors. A more inclusive and adaptable work environment is fostered through the creation of adaptive workspaces, where technology adjusts to human requirements and preferences, fostering a better work-life balance and overall job satisfaction. In IR 5.0, technology is used to enhance and empower the workforce, ensuring that innovation and advancement are focused on bettering people's lives.

4.1.3. Economic Efficiency

Using cutting-edge technology like artificial intelligence (AI), automation, and data analytics, Industrial Revolution 5.0 promotes economic efficiency. These developments improve resource allocation, lower operational costs, and optimize production processes. For instance, AI-driven supply chain management assures just-in-time inventory and cost savings, while predictive maintenance enabled by IoT sensors reduces downtime and maintenance costs. Additionally, IR 5.0's customizable features help companies effectively satisfy the demands of each customer. This emphasis on accuracy, adaptability, and data-driven decision-making increases productivity while also fostering competition in a global economy that is continually changing.

4.1.4. Resilience

Industrial Revolution 5.0 encourages flexibility and risk management, which increases the resilience of industries and economies. Businesses may monitor and respond to interruptions in real time using cutting-edge technologies like AI, IoT, and digital twins, assuring business continuity. Predictive analytics, for instance, can spot possible supply chain problems, enabling early actions to safeguard essential resources. Additionally, by lowering sensitivity to environmental and energy-related problems, smart infrastructure, and the use of renewable energy boost resilience. Businesses and societies are better prepared to endure and recover from diverse crises thanks to IR 5.0, which encourages a more flexible and responsive approach to both planned and unforeseen disturbances.

4.2. IR 5.0 and Managerial Insights

The development of cutting-edge technology, including automation, artificial intelligence, and big data analytics, has had an enormous effect on managerial insights. Today's managers can view enormous volumes of real-time data that may be examined to learn a great deal about consumer behavior, market dynamics, and operational effectiveness. This enables them to execute successful strategies that spur growth and enhance organizational efficiency while making data-driven decisions [59]. Furthermore, IR 5.0 empowers managers to make proactive decisions by utilizing predictive analytics and machine learning systems to estimate future events more accurately. Overall, IR 5.0 equips managers with useful information from tech-based systems and resources, enabling quick decisions that may be adjusted to business contexts that are evolving frequently.

5. Conclusions

The impact of the fifth revolution on many industries, such as the construction industry, cannot yet be determined due to the unavailability of adequate resources and skills. Although the world is shifting from IR 4.0 to IR 5.0, the concept of IR 5.0 is still in its early stages as industry professionals are working to streamline and ease the integration of humans with machines instead of replacing them. Considering the significance of the adoption of IR 5.0 in the construction industry, the current review study is conducted to assess the transformational changes within different industrial revolutions and a way forward for the adoption of IR 5.0 in the construction industry. Furthermore, through a policy framework for decision-makers, the present study has tried to fill an important role by providing a way forward for the construction industry professionals to transform themselves in the era of IR 5.0

The findings of the current study highlight that Industry 5.0 can promote innovation in how we interpret large data by incorporating changes into the design of future innovation ecosystems. Without compromising the viability and security of an innovative ecosystem and its constituent parts, Industry 5.0 envisions a world of linked networks. This revolution aims to provide accountability while utilizing the most automation and big data analysis possible. Robots have historically played significant roles in manufacturing and production facilities, but the most recent generation of collaborative robots is fitted with sensors that allow them to perform tasks other than mechanical and repetitive ones. The results of the current review also indicate that in some applications, robots collaborate with people to promote a higher level of product customization. The integration of human intelligence and cognitive computing with machines will be at the heart of the Fifth Industrial Revolution. Innovation in construction has been critical to this transformation, with new materials, techniques, and tools being developed to improve productivity and reduce environmental impact. For example, the use of 3D printing in construction is enabling faster and more efficient construction of buildings and infrastructure, while also reducing waste and energy consumption.

Similarly, the study has also identified that another area of innovation in construction is the development of smart buildings that use sensors and data analytics to optimize energy use and improve the comfort and safety of occupants. The use of advanced materials such as biodegradable composites and self-healing concrete is also enabling more sustainable construction practices. The interaction between people and machines alters many aspects of production and has an impact on the economy and ecosystems. Manufacturers are under pressure to reduce costs due to fierce competition, which can be achieved by producing zero waste. Zero waste production, which emphasizes the human component of manufacturing, helps maintain a healthy environment. It is time to go from Industry 4.0 to Industry 5.0, where robots and human intelligence will enhance cyber–physical systems, considering the societal implications of Industry 4.0. The key differences between IR 4.0 and IR 5.0 include the shift of focus from integrating machines to delivering customer experiences, mass customization to hyper customization, intelligent supply chains to responsive and distributive supply chains, smart products to interactive products, and manpower distanced from factories to the return of manpower to their workstations. Thus, future work will be conducted in virtually every industry and will be based on the massive amounts of data supplied by these IoT devices. The industrial process is reinforced with value addition that promotes mass personalization by reintroducing human interaction with collaborative robots. Although the fifth revolution is still in its early stages, businesses are attempting to go forward with it sooner because they want to outperform their rivals. As a result, the knowledge gained from the analysis of Industry 5.0 is further distilled to define a new research program.

5.1. Practical Implications

A review of the potential effects Industrial Revolution 5.0 can have on the construction industry suggests some real-world implications, including the adoption of cutting-edge technologies like AI, IoT, and automation for increased project efficiency, the incorporation of digital twins and BIM for better project management, the use of smart materials for sustainable construction, and the use of renewable energy sources for eco-friendly infrastructure. Adopting these advances can result in more effective, environmentally friendly, and technologically sophisticated construction practices, ensuring the sector is competitive and prepared for the future.

5.2. Managerial Implications

A study on the future of building through Industrial Revolution 5.0 has important managerial ramifications. Construction managers and leaders must invest in the training and development of their employees to be ready to react to rapid technological advances. Additionally, they want to reevaluate conventional project management strategies and switch to more collaborative, data-driven techniques to take advantage of innovations like BIM, digital twins, and predictive analytics. Additionally, as smart materials, renewable energy integration, and modular building methods become crucial elements of future projects, innovation and sustainability should be at the center of their strategic planning. Construction managers can position their businesses for success in the changing construction landscape, fueled by Industrial Revolution 5.0 technology, by embracing these changes.

5.3. Recommendations and Limitations for Future Research

It has been highlighted already that the concept of IR 5.0 is novel and is in its early phase of development. Through this review study, IR 5.0 adoption has been discussed comprehensively, however, the following are various recommendations and future agenda items in the context of the current subject area:

1. It is recommended to explore the education and training workshop requirements for preparing the workforce of the future to be equipped with the relevant skills and knowledge in the era of IR 5.0;
2. The adoption of IR 5.0 in the context of the construction industry should be explored with a greater focus on the economy, society, and the environment;
3. Government agencies, policymakers, decision-makers, stakeholders, and investors should collaborate to increase investments and minimize the regulatory hurdles in the adoption or implementation of IR 5.0-enabling technologies;
4. The concept of IR 5.0 should be explored with the inclusion of real-world case studies. Although, at this moment, due to the unavailability of resources and skills, it would be a difficult job, but still, making some progress is better than no progress at all;
5. The concept of IR 5.0 has not been assessed adequately in the context of sustainability. The challenges and limitations are abundant, but they can be removed through the engagement of major industry stakeholders from public and private organizations.

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