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The TQM J

Systematic review of Industry 5.0 from main aspects to the execution status

Journal:	*The TQM Journal*
Manuscript ID	TQM-06-2023-0183.R1
Manuscript Type:	Research Paper
Keywords:	kaizen, Operations management, Lean Production, Industry 4.0

A systematic review of Industry 5.0 from main aspects to the execution status

Abstract

Purpose: The main aim of this study is to review different aspects of Industry 5.0 (I5.0) to foster this novel aspect of industrial sustainability. The study makes a comprehensive study to explore the implementation status of I5.0 in industries, key technologies, adoption level in different nations, barriers to I5.0 adoption together with mitigation actions.

Methodology: To do a systematic study of the literature authors have used preferred reporting items for systematic reviews and meta-analysis (PRISMA) methodology to extract articles related to the field of the study.

Findings: It has been found that academic literature on the I5.0 is continuously growing as the wheel of time is running. Most of the studies on I5.0 are conceptual-based, and manufacturing and medical industries are the flag bearer in the adoption of this novel aspect. Further, due to I5.0's infancy, many organizations face difficulty to adopt the same due to financial burden, resistive nature, a well-designed standard for cyber-physical systems, and an effective mechanism for human-robot collaboration. Further study also provides avenues for future research in terms of the identification of collaborative mechanisms between machines and wells, the establishment of different standards for comparison, development of I5.0-enabled models for different industrial domains. The study also provides concrete measures for mapping the I5.0 technologies with Sustainable development goals (SDGs).

Originality: The study is of the first kind that reviews different facets of I5.0in conjunction with Kazien's measures along with application areas and provides avenues for future research to improve an organization's environmental and social sustainability.

Keywords: Industry 5.0; Kaizen; Systematic literature review; Big data; Internet of Things; Machine learning; Human-centred system; Sustainable development goals (SDGs)

1. Introduction

Increased globalization, shorter product life cycle, demand for sustainable products, and issues related to social and environmental effects have forced industries to adopt modern technological measures that stay at competitive platforms (Kaswan et al., 2023a; Yadav et al., 2023). Most organizations throughout the world are being operated with traditional quality improvement methods like Lean, Total Productive Maintenance, Six Sigma, Lean Six Sigma, etc. But these approaches are not able to address challenges related to environmental emission mitigation and mass customization of products (Rahardjo & Wang, 2022; Rathi et al., 2021). Over the last two decades, there is an increasing boom to adopt digital technologies named Industry 4.0 (I4.0) to make the system response faster, error-free, and deliver high-quality items (Yadav et al., 2020a; Yadav et al., 2023b). I4.0 is a new technological paradigm model that encompasses technologies like Artificial Intelligence, Machine Learning, Cyber Security, Big Data, etc. (Zizic et al., 2022). Although I4.0 leads to improve organizational efficiency in terms of reduced defects waste, and labour hours but it is not able to address issues related to social and environmental sustainability (Kaswan et al., 2023b). Different continuous improvement measures (Kaizen) are demanded to make holistic improvements coupled with a set of digital technologies. I4.0 is highly technologically centred and neglects the human aspects within the complete production system (Malik et al., 2023; Rathi et al., 2022). It does not include aspects related to human thinking, emotions, and wellness of human beings that are critical to assure that the workplace is more friendly and accidental-free (Malik et al., 2023). The incorporation of human aspects within the production system enables the work system safer, and more reliable, and leads to improve organizational social sustainability (Kumar et al., 2023; Kaswan et al., 2023c).

The history of I5.0 can be traced back to the development of different industrial revolutions. Industry 1.0 was related to the invention of the steam engine which leads to the mechanization of production (Leng et al., 2022). Industry 2.0 was more related to electricity and combustion engines where the focus in the 19th century was to electrify the mechanical production system (Akundi et al., 2022). The electricity produced is more conveniently used for production as compared to steam which needs water for production and hence makes the electricity transfer way easier. Industry 3.0 was more oriented toward the issues of digitization, automation, and the internet where the internet was taking over for calculations and data transfer, and digitalization of data was taking place (Xu et al., 2021). With the developments of electronics and computer technologies, the 20th century made human life and industries more commendable and regulated and the difficult tasks at the industry level became a walk on the cake. This revolution also introduced the humans look alike Robots which are working as a team to achieve automated production with higher accuracy. I4.0 was more about various automation technological developments such as Robotics, Artificial Intelligence, IoT, and

Blockchain ((Yadav et al., 2020b; Zizic et al., 2022). The advancements in information and communication technology lead to the digitalization of industries. This establishes the communication networking of all the systems prominent to cyber-physical-production systems. I5.0 would cater to the customers with personalized and customized products which would reassure the diversified customer base and hence mass personalization can be targeted. I5.0 would emerge with a Human-centred system apart from machined-centred I4.0 by employing the cognitive thinking of humans to the required tasks while assigning the continual tasks to the rapid and accurate IT-enabled integrated machines and robots. I5.0 encompasses different kaizen measures for the incorporation of the human being that leads to improved cognitive thinking of the human and that leads to improved work safety at the workplace (Fazal et al., 2022). I5.0 is a design solution that puts people first (Javaid et al., 2020). The ideal human companion and collaborative robots (cobots) work with human resources to make autonomous manufacturing that is tailored to each person possible through enterprise social networks. This, in turn, makes it possible for people and machines to work together. Cobots are not machines that can be programmed, but they can sense and understand when a person is nearby. In ideal situations, cobots will be used for repetitive tasks and work that requires a lot of physical labour, while humans will handle customization and critical thinking (Hanif & Iftikhar, 2020). Table 1 depicts different industrial revolutions with their salient features.

Table 1: Different industrial revolutions (Source: Authors' own creation)

1st Industrial Revolution	**2nd Industrial Revolution**	**3rd Industrial Revolution**	**4th Industrial Revolution**	**5th Industrial Revolution**
Mechanisation	Electrification	Automation and Globalisation	Digitalisation	Personalisation
Occurred during the 18th Century mainly in Europe and North America	From the late 1800s to the start of the First World War	The digital revolution occurred around the 1980s	Start of the 21st Century	2nd decade of the 21st Century
Steam engines replacing the horse and human power	Production of steel, electricity, and combustion engines	Computers, digitization, and the internet	AI, robotics, IoT, blockchain	Innovation, purpose, and inclusivity
Introduction of mechanical production facilities driven by water and steam power	Division of labour and mass production, enabled by electricity	Automation of production through electronic and IT systems	Robotics, artificial intelligence, augmented reality, virtual reality	Multi-level cooperation between people and machines Consciousness

I5.0 is in its infancy stage so to boost the application of I5.0 in various industrial segments, therefore, it is imperative to comprehend its different facets know-how success factors, barriers, and technologies. For this, it is the need of the hour to develop a comprehensive review of I5.0 that provides systematic guidelines to practitioners, managers, academicians, and researchers. I5.0's focus on environmental and social sustainability aspects provides an impetus to conduct this systematic study of I5.0 literature.

This article consists of eight sections including an introduction. Section 2nd depicts the literature search methodology and descriptive statistics of the articles are presented in section 3 of the article. Section 4 illustrates industrial applications of I5.0 whereas key technologies of I5.0 are presented in section 5. Section 6 states barriers to I5.0 execution along with mitigation strategies. Linkage of I5.0 with sustainable development goals (SDGs) and social sustainability aspects have been provided in the 7th section. Future aspects of the review are presented in section 8. The final section of the manuscript presents inferences drawn from the study.

2. Literature search methodology

The research work uses a Systematic Literature Review (SLR) methodology to conduct a comprehensive review of I5.0. SLR induces methodological stringent review as compared to general review with a focus on evidence-based guidelines for research. In this research work, the authors used the SLR methodology suggested by Tranfiled which encompasses, the planning, and reporting stages.

2.1 Planning stage

This stage enumerates the need for review and developing a review protocol. This paper review I5.0 and direct the same to tap the full potential of the digital approach cantered with human need through the exploration of application areas, challenges, and development of possible research agenda. Table 2 shows the adopted review protocol for the study.

Table 2: Review protocol (Source: Authors' own creation)

Unit of analysis	**Articles of Industry 5.0**
Analysis type	Qualitative
Study time frame	2013-2022
Field of search	Keywords, title, abstract
Databases	Science Direct, Web of Science, Emerald, Scopus

2.2 Conducting review

This stage states the collection of studies and their analysis by extracting data. In this study, the authors used databases of Science Direct, Web of Science, Emerald, and SCOPUS so that all pertinent articles can be included in the study. The study encompasses peer-reviewed articles to ensure the quality of publications. The selection period of the study was from 2013 to

2022. The year 2013 has been selected because this was the inception of studies related to human-centric I5.0 technologies in the research domain.

Table 3: Keywords with the label (Source: Authors' own creation)

Keywords	**Label**
Human-centric digital technologies	HCDT
Industry 5.0	I5.0
Digital technologies and human	DTH

Table 3 depicts keywords along with their respective labels. A snowball approach has been adopted in this study for search criteria of the keywords to further explore terms related to I5.0. For example, I5.0 has been replaced with digital technologies and human; Human-centric digital technologies. Articles have been explored from the electronic databases by incorporating keywords in the following expressions.

X = [HCDT, I5.0, DTH]

where, X[1]= HCDT, X[2]= I5.0, X[3]= DTH]

XT= X[1]=|| X[2]=|| X[3]……………………………………………………(1)

where XT = total, ||= OR

The other selection criteria used for the study is the English language only for the papers. The criteria used resulted in all 232 articles at the initial stage of the study including review articles. Further, to eradicate duplicate articles authors used end note software. This resulted in the exclusion of a further 80 articles.

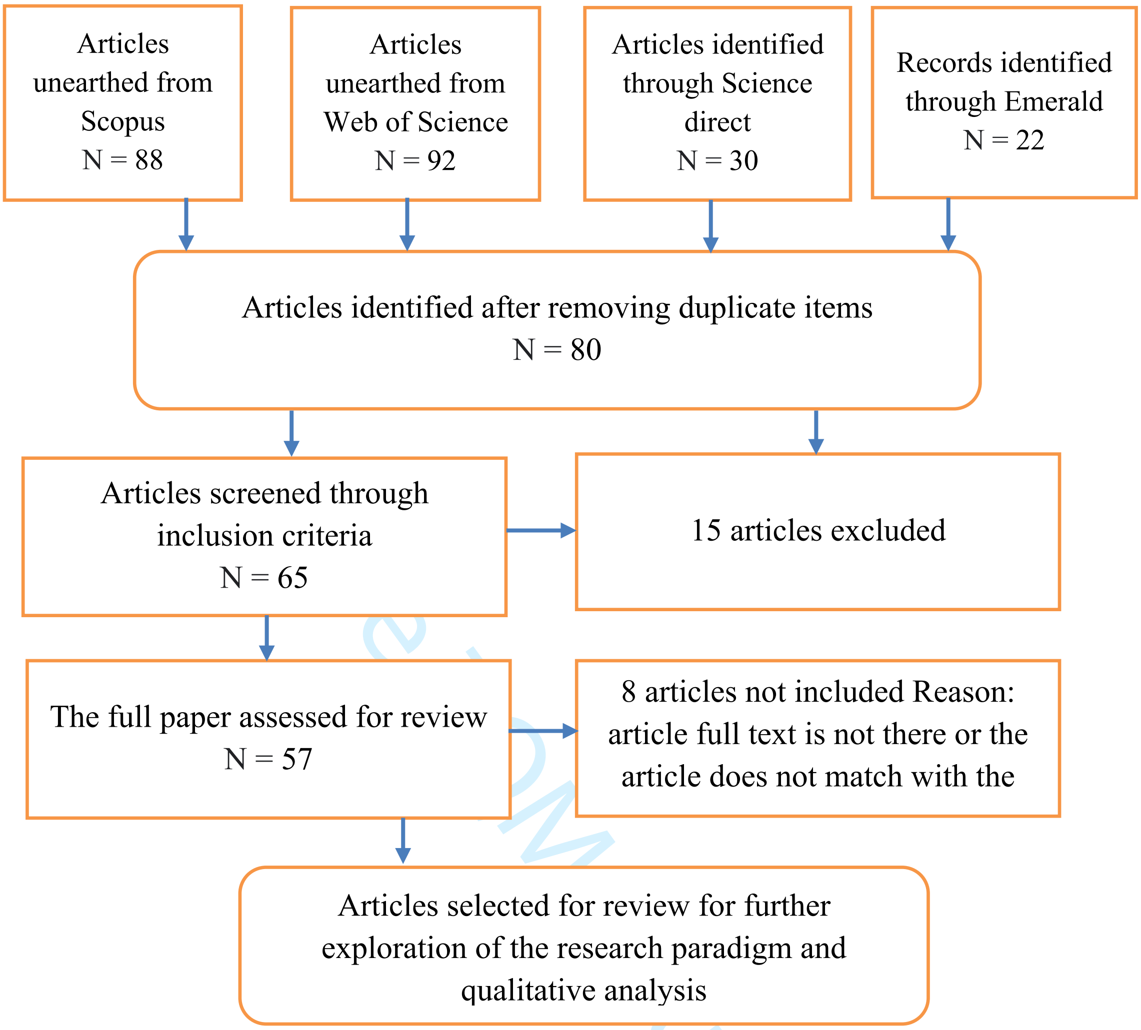

Figure 1: Preferred reporting items for systematic reviews and meta-analysis (PRISMA) flowchart. (Source: Authors' own creation)

Authors filtered documents and applied inclusion criteria, the abstract of 80 articles was further analyzed to match the same objectives of the study which lead to the further exclusion of the 15 articles. Thereafter, the full-text availability of the articles was considered, that further led to the exclusion of 8 more articles. In the final stage of the review content of the articles was analyzed according to the relevance of the topic, this further led to the exclusion of 5 articles. The PRISMA method has been used in this study to filter articles related to the topic of interest. The final sample encompasses 52 articles, after careful consideration of the articles. The said number of articles was further analysed in the reporting stage to find potential applications, challenges, and prospects of the I5.0. The authors also conducted a descriptive analysis of the article country-wise, authors-wise, and year-wise to the scenario of the applications of I5.0 technologies to know the trend and major contributors to the same field.

3. Descriptive statistics of Industry 5.0

This section consists of three subsections. Subsection 3.1 represents a descriptive analysis of the published articles, country-wise, industry-wise and year-wise to explore different aspects of I5.0. Subsection 3.2 denotes the development of I5.0 and the exploration of the area of research from previous studies.

3.1 Journal-wise distribution of articles

The current work covers articles from 43 reputed journals/proceedings about the field of research in the Fifth Industrial Revolution. Maximum of 3 articles were taken from Computers & Industrial Engineering (6.25%) followed by the Applied System Innovation (MDPI) (4.16%), Journal of Industrial Integration and Management (4.16%), and Applied Sciences (MDPI)(4.16%). Table 4 depicts the journal-wise distribution of the articles.

Table 4. Journal-wise distribution of articles *(Source: Authors' own creation)*

S. no.	Journal Title	No. of Articles	Percentage of Articles
1	Computers & Industrial Engineering	3	6.25
2	Applied System Innovation (MDPI)	2	4.16
3	Journal of Industrial Integration and Management	2	4.16
4	Applied Sciences (MDPI)	2	4.16
5	Journal of the knowledge economy	1	2.08
6	Journal of Retailing	1	2.08
7	An Acad Bras Cienc	1	2.08
8	Proceedings on Engineering Sciences	1	2.08
9	Energy Conversion and Management	1	2.08
10	Muhammadiyah International Journal of Economics and Business	1	2.08
11	Pakistan Journal of Surgery and Medicine	1	2.08
12	Journal of Machine Engineering	1	2.08
13	International scientific journal "Industry 4.0"	1	2.08
14	Quality innovation prosperity	1	2.08
15	IEEE transactions on engineering management	1	2.08
16	Social Science Research Network	1	2.08
17	The Eurasia Proceedings of Science, Technology, Engineering & Mathematics	1	2.08
18	Journal of Innovation & Knowledge	1	2.08
19	Information (MDPI)	1	2.08

20	Engineering	1	2.08
21	Sustainability (MDPI)	1	2.08
22	International Research Journal of Engineering and Technology	1	2.08
23	Scientrometrics	1	2.08
24	10th International Conference on Through-life Engineering Service	1	2.08
25	Mathematical Biosciences and Engineering (AIMS)	1	2.08
26	Current Medicine Research and Practice	1	2.08
27	Journal of Clinical Orthopaedics and Trauma	1	2.08
28	3rd World Conference on Technology, Innovation, and Entrepreneurship	1	2.08
29	Journal of Industrial Information Integration	1	2.08
30	International Conference of Technology, Innovation and Industrial Management	1	2.08
31	Journal of Seybold Report	1	2.08
32	International Journal of Advanced Computer Science and Applications	1	2.08
33	Sustainable Production and Consumption	1	2.08
34	Adel Journal of Cloud Computing	1	2.08
35	Energies (MDPI)	1	2.08
36	International Journal of Engineering and Advanced Technology	1	2.08
37	IEEE transactions on industrial informatics	1	2.08
38	Soft Computing	1	2.08
39	Review of International Comparative Management	1	2.08
40	A Journal of Integrative Biology	1	2.08
41	Journal of Yasar University	1	2.08
42	Proceedings of the 5th International Conference on Industrial Engineering and Operations Management	1	2.08
43	Sensors(MDPI)	1	2.08

3.2 Country-wise Distribution of Articles

Figure 2 shows the country-wise distribution of the articles where a major contribution of articles is from India (22.91%), followed by the USA (10.41%) and Turkey(8.33%). Both Malaysia and England contributed the same i.e. (6.25%) afterwards. It has been found that around one-fourth of research, articles have been submitted by Indian authors however USA and Turkey authors also have significant contributions in this field.

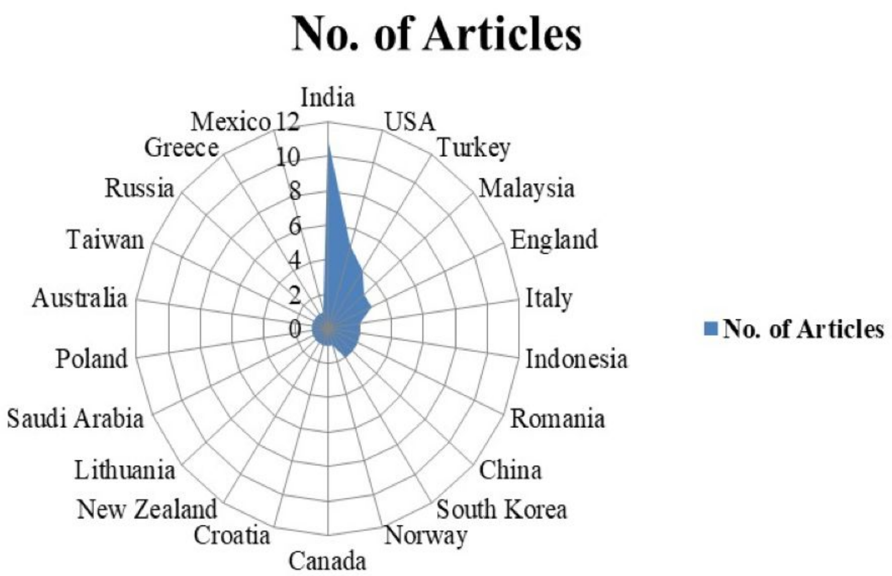

Figure 2: Country-wise number of articles *(Source: Authors' own creation)*

3.3 Year-wise distribution of articles

Figure 3 shows year wise number of articles. A maximum number of articles i.e., 15 came in the year 2022 followed by 13 articles in 2021 and 9 articles in 2020. Furthermore, 7 articles came in 2019, 2 articles in the year of 2018, and 1 article each came in the years 2017 and 2016. This trend indicates that the concept is emerging rapidly within the last 5 to 6 years and therefore addressing this concept is worthful.

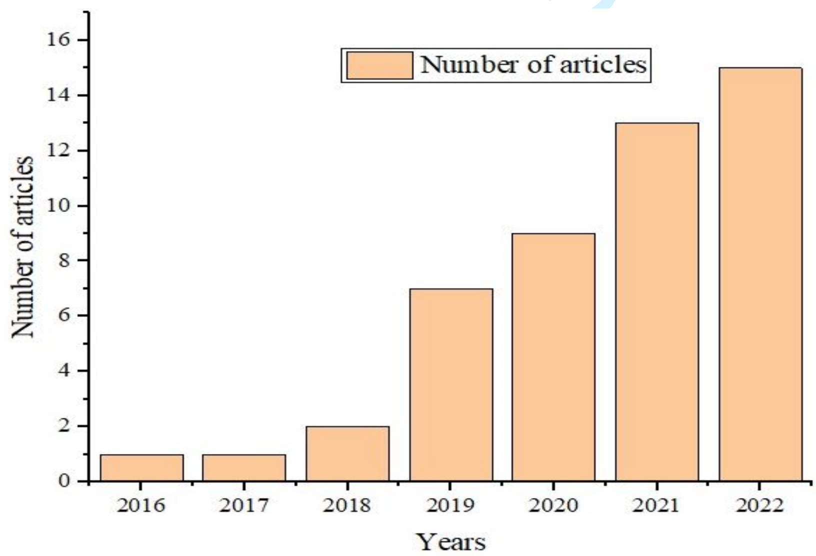

Figure 3: Year-wise number of articles *(Source: Authors' own creation)*

3.4 Exploration of Frameworks of Industry 5.0

Table 5: Framework of Industry 5.0 (Source: Authors' own creation)

Authors	Contribution	Operational benefits	Sustainable benefits	Practical case implementati
Ghobakhloo et al.,2022	Developed i5.0 enabled model for sustainable development using interpretive structural modelling for identifying sequential relationships among the constructs. The study provides a comprehensive road map for sustainable development through the identification of different key technologies concerning different SDGs.	–	👍	–
Sharma et al., 2022	Proposed a functional framework of the I5.0 based on four key concepts named: intelligent and sustainable supply chain; intelligent and sustainable manufacturing; collaborative and cognitive working and mass and hyper-customized products.	👍	👍	–
Ivanov, 2022	Developed a framework of I5.0 through the lens of the viable supply chain model, the reconfigurable supply chain, and human-centric ecosystems.	–	👍	–
Sindhwani et al., 2022	Proposed a framework for analyzing I5.0 enablers for achieving sustainability by integrating human values with technology.	👍	👍	–
Ghosh et al., 2022	Developed a detailed Cognitive Routing Framework for Reliable Communication in IoT for Industry 5.0 applications.	👍	–	–
Babkin et al., 2022	Proposed a digital development framework provides grounds for a digital business strategy to advance and shapes a platform-operating model to nurture the digital maturity of industrial systems.	👍	–	–

I5.0 adoption is still in its infancy at the execution level. It has been found from the existing frameworks that they are conceptual and the implementation part is not explored at all. The reasons for the same can be attributed to lack of exposure to the I5.0 to industrial personnel, technical know-how of I5.0, and change in technological aspects of the organization due to the adoption of I5.0. The same can be overcome by providing a detailed technological knowledge base and training to the employee about the potential benefits of I5.0 related to all aspects of sustainability.

4. Exploration of key studies on Industry 5.0 in the different industrial fields

The last industrial revolution i.e., Industry 4.0 was more about automation at its centre and not considered the human factor, therefore need is arising for a more innovative approach that will consider the human aspect along with automation of systems (Zizic et al., 2022). Now, I5.0 is not limited to the manufacturing sector but extended to other areas also such as medical applications, computers and electronics, food processing, construction, and many more. It has been found that a systematic review is unarguably required which shall cover all the concerned sectors and the literature available in those fields as well.

Figure 4 shows the industry-wise distribution of articles pertaining to I5.0. Major contributors were conceptual and descriptive-based articles (54.16%), followed by manufacturing-based articles (20.83%), medical applications-based articles (12.5%), and electronics and computers-based articles (8.33%). Least contribution with a percentage of (2.08%) from each of the Construction/Infrastructure and Food processing related articles. The data indicate that the exploration is only at the level of conceptualization and there is still a lack of proper implementation at the ground level for I5.0.

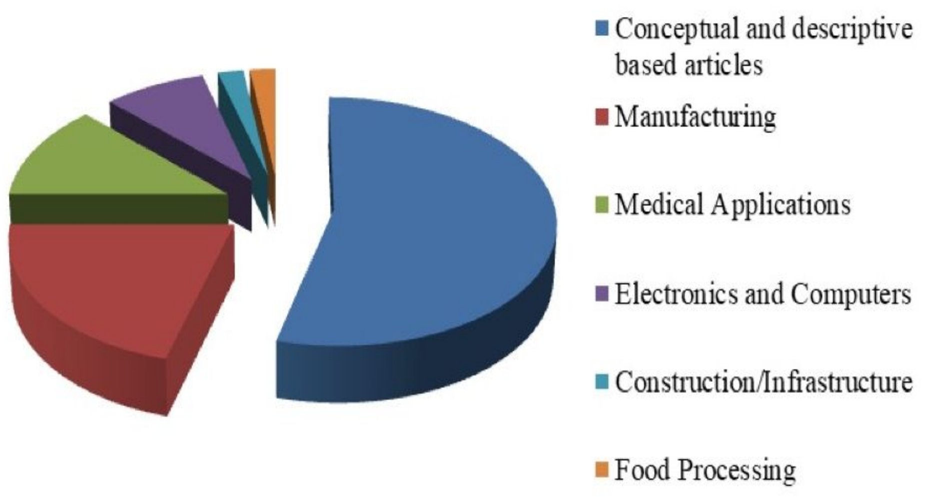

Figure 4: Industry-wise number of articles *(Source: Authors' own creation)*

4.1 Conceptual and Descriptive based studies

The intentions of the concept of Industry 5.0 are truly focused on making industries resilient, human-centric, and sustainable. The majority of organizations are in the process of adapting to I4.0, and debates and dialogues already started for the 5th industrial revolution (Nahavandi, 2019a). The origin of I5.0 can be easily traced back to the year 2010 when social media posts ignited the spark of the new industrial revolution by Michael Rada (Akundi et al., 2022). In his LinkedIn post, he termed this new revolution as Industrial upcycling. He coined the term and a new concept also where complete automation will be replaced by the technologies such as Cobots, where the human and robots will work together for the betterment of systems as it was sensed that the human touch has been completely ignored in the concept of I4.0. The birth of the 5th industrial revolution gives hope that in the future, industries will not only fill bank accounts but also feed more and more stomachs without halting the progress of technology. A bibliometric analysis of the birth and growth of I5.0 found that the publications in this field are of limited number and even those that are available, are explaining the concepts in various ways (Madsen & Berg, 2021). However, no study has tried to cover the areas where this new revolution can present its impact. Another conceptual article attempted to identify the impact of Artificial Intelligence in the employment sector considering I5.0 (Çağda et al., 2021). It has been found that the adaptation of AI in I4.0 has side-lined the human factor and therefore more intensive and rapid work is required keeping in mind the target of I5.0. Another study has attempted to review the transformation towards I5.0 from I4.0 and the highlights of the study were the concerns and features while the transformation is in progress and the concerns addressed more constructively (Zizic et al., 2022). It is shifting the complete focus on the effects of this transformation on humans and organizations as well as how industries and researchers are tackling this transformation. Another conceptual work attempts to explore the innovation areas, challenges, and hurdles in the future while implementing the technologies of I5.0 (Adel, 2022). With the help of available literature, the study has enlightened the possible obstacles while implementing various enabling technologies such as IIOT, human-machine interaction, cloud computing, and many more. This work also tried to present the challenges when the actual implementation of various technologies will start at ground level. Attempts have been done to identify the path to sustainable development and how I5.0 will contribute to this pathway (Ghobakhloo et al., 2022). The nutshell was to identify the functionality of I5.0 while delivering the targets of sustainable development. Interpretive Structural Modeling (ISM) has been used for identifying the relationship between the build and functions of an I5.0-driven structure. Attempts have been made by another article to enlighten the role of enabling technologies in the implementation of I5.0. It considered technologies such as collaborative robots, edge computing, Digital twins, blockchain, cloud computing, big data, IoT, AI, and many others (Humayun & Arabia, n.d.). It considered various articles in context with concerned technologies and concluded that in the future, industries will become obsolete if I5.0 is not implemented effectively as human-robot collaboration and human-centric approach are the future of Industries. So, it can be deduced that most of the studies about I5.0 in the literature are conceptually based, a complete exploration of barriers, industry-wise application, and technologies still need a full exploration to make this new industrial paradigm more convenient for the workforce and industrial managers.

4.2 Manufacturing industries

The major impact of industrial revolutions is undoubtedly on the manufacturing sector and therefore the journey of the transformation from I4.0 to I5.0 has been explored regarding current manufacturing processes to the I5.0-enabled processes (George and George, 2020). Identification of bottlenecks has been done during the phase of transformation in terms of ethical concerns, regulatory issues, social issues, and legal hurdles. It has been concluded by them that the ground-level challenges can be addressed when the robots and humans will start working together collaboratively. Impact identification of Industry 5.0 has been done by another conceptual study and concluded that most of the organizations trying to ignore I5.0 because of a lack of infrastructure the capital involved during the journey of transformation (Paschek et al., 2019.). It has been concluded that owing to the lack of proper awareness of the governing factors of implementation and due to fear of uncertainty, organizations are hesitating to adapt to the I5.0 concepts and technologies. Fields related to sustainability and humanization have been explored while achieving I5.0 and more focus has been put on human skill enhancement while addressing the transformational journey from I4.0 to I5.0 (Grabowska et al., 2022). Conclusions were drawn that more futuristic professions are bound to emerge during this transformation such as mobile robot managers, machine programmers, robot assistants, process controllers, device teachers, chief robotics officers, and many more. The major focus was on the fact that skill enhancement is the most important factor during this transformation, and it needs to be tackled aggressively for proper implementation of I5.0 enabling technologies. It has been also concluded that exploring the human skill enhancement field is very critical to achieve the I5.0 targets as the very core of the 5th Industrial Revolution is the human-centric approach. Potential applications of I5.0 have been studied considering the scenario of Covid-19 and attempts have been done to identify the considerable obstacles in the atmosphere to COVID-19 fears, in the journey of transformation towards I5.0.(Javaid et al., 2020). It has been found that the overall treatment process of the patient can be improved if the enabling technologies such as Big Data and the Internet of Things are utilized properly during the treatment. The detection process and treatment selection process can be greatly enhanced with the help of enabling technologies of I5.0. Another study aims to compare, examine, and describe the enabling technologies while implementing I5.0 regulations (Kumar Birda & Dadhich, 2022). The study claims to provide insights into the implementation process for I5.0

as well as present pathways to tackle upcoming obstacles, for instance, Covid-19 measures and hurdles in man-machine collaboration. Another article attempted to identify the obstacles in the implementation of the I5.0 framework owing to the lack of practical innovation management from work (Aslam et al., 2020). Literature review methodology has been used for developing AIM (Absolute Innovation Management) framework that considers everyone within the organization for proper functionality and utilizes time and space effectively.

Issues during the implementation of I5.0 in the transportation sector especially electronically driven passenger vehicles have been presented and the prime focus was on (ISTMA) Integrated Sustainable transporting modelling approach for (EPV) Electronic Passenger Vehicles (Qahtan et al., 2022). It has been found that the new technique presented by integrating (MULTIMOORA) Multiplicative multi-objective optimization by ratio analyses with P-H-FWZIC for facilitating as well as solving problems linked to the ISTMA benchmarking in the context of EPV considering regulations and concepts of I5.0. Lean Innovation Approach has been used in processes of research projects in the context of I5.0. The study explored effective value management and its introduction to the lean approach concerning I5.0 implementation (OZKESER Koluman Otomotiv Endüstri AŞ, 2018). Even with regards to I4.0, important characteristics were critically investigated as well a required separate paradigm was introduced termed Lean Six Sigma (LSS). It has been found that for implementing properly the advanced paradigm of LSS, 9R success factors need to be followed. Another article attempts to outline recent technologies, for instance, IoT, and their convergence in the transformation from I4.0 to I5.0 (Skobelev & Borovik, 2017). Another investigation of I5.0 enabling technologies has been conducted and the major analysis was related to Big Data, Artificial Intelligence, and the IoT. The study claims that I5.0 bring revolutionary changes in the manufacturing sector across the globe as the repetition processes are bound to be done by robots and innovative tasks such as decision-making should be done by humans (Mourtzis et al., 2022). Preparation and obstacles during the implementation of I5.0 in Indonesian medium and small enterprises had been addressed in an article where the analysis was done according to available sources. Another article contributes to I5.0 enabling IOT technology in the context of warehouse automation and Plant (Fatima et al., 2022). It also elaborates Industrial Internet of Things (IIOT) beyond IoT to understand and remove the obstacles in the implementation of IIOT in the industrial sector. The authors concluded that IIOT is the key technology for better implementation of I5.0 enablers. The field of clean bioenergy generation in the context of I5.0 and its prospects in algae has been studied (ElFar et al., 2021). The article reviewed the processing and production of algae through an industrial viewpoint and in context with the transformation from I4.0 to I5.0. Effects of the advanced cultivation process, advancement in biofuels, and their effect on algae production have been studied and their relationship with I5.0 technologies is drawn out. Another conceptual article analyzed customer value chain involvement (CVCI) and considered it vital while implementing I5.0 technologies (Durmaz & Kitapcı, 2021). The focus of this study was on the necessity of human factors for mass personalization and product development concepts. The study put focus on the human-technology co-operational effect on the atmosphere. Recent research trends have been identified and analyzed in context with I5.0. Text mining techniques and tools were used in this study. Enabling technologies and their influence has been analyzed such as the Internet of Things, Machine Learning and Digital Transformation, supply chain, and Artificial Intelligence. For thematic aspects of papers regarding I5.0, the topic analysis technique was applied. The study concluded that the most contributed technologies involve Machine Learning, Big Data, Artificial Intelligence, and Supply chain. Emerging technologies and technological competitiveness have been analyzed for I4.0 and I5.0 (Alvarez-Aros & Bernal-Torres, 2021). A systematic review and bibliometric analysis have been done by the authors and the results were in favour of big data, the IoT, and supply chain as key technologies for I5.0. Findings also suggest the requirement of new policies as well as better ethical and political comprehensiveness is desired. Service and retail domain analysis has been done in the context of I5.0 (Noble et al., 2022). The article claims to present the pathway after forecasting the growth of I5.0 implications for service and retailing. The study tries to suggest that future managers in understanding man-machine relations considering I5.0. Another study explored fusion energy and its geopolitical status quo in the context of Society 5.0 and I5.0 (Carayannis et al., 2021). Ethical technology and Value-oriented engineering in context with I5.0 has been analyzed and the findings suggested that the value system does not have absolute stability and is very much affected by transforming production strategies, socio-culture issues, and updating work (Longo et al., 2020).Further, a case study has been done by considering the best-worst method to analyze challenges related to I4.0 and the analysis has been done in context with the manufacturing domain and automobile components manufacturing industries (Wankhede & Vinodh, 2021). Findings suggested that implementation of I4.0 required trained manpower and upgraded infrastructure. So, it can be deduced that I5.0 although find applications in manufacturing need more exploration in terms of interconnection among human-machine-centric systems, and exploration of social and environmental aspects through the use of I5.0 technologies and associated tools of operational excellence approaches.

4.3 Construction industries

Industry 5.0 also found applications in construction and other allied industries. In this concern, a study attempts an analysis of distance-ranging environment monitoring technology in the context of I5.0 characteristics from the viewpoint of smart city infrastructure(R. Sharma & Arya, 2022). Analysis of various parameters has been done, for instance, regression parameters, correlation coefficients, and Eigenvalues from the information recorded. Findings suggested that the pollutants level is raising hour by hour and data on air quality can be transmitted to a cloud server by UAV only. Construction industries are booming in developing nations like India, use of I5.0 technologies can revolutionise this sector through the use of additive manufacturing and associated AI tools. This will reduce the time required for the construction of big projects on complicated sites.

4.4 Electronics and computers industries

Industry 5.0 has found considerable applications in electronics, computers, and allied industries also, for instance, in the field of cyber-physical systems, the study has been carried out to present architectural approaches accompanied by system-developed prototypes to address the convergence issue of operation and information technology domains (Patera et al., 2022). Circular value chain analysis also has been done in the context of I5.0 enabling technologies. Findings suggested a model in favour of hyper customization and intelligent supply chains. In the area of cyber-physical systems, another study carried analysis related to emerging architecture with regards to smart cyber-physical systems, heterogeneous architecture has been proposed which combines various processes such as hydraulic, pneumatic, and electrical for the execution of hybrid process dynamics (Thakur & Kumar Sehgal, 2021). Another study analyzed End-to-End transmission control concerning IIOT in the context of I5.0. It discussed various aspects of IIOT and data transmission for proper implementation of I5.0. The applicability of heterogeneous network transmission is confirmed experimentally in this article and an analysis of data transmission for heterogeneous networks has been done. Application of AI and human intelligence for the Cyber-physical system (CPS) has been done and the prime focus was on man-machine cooperation and functionality of cobots (Pathak et al., 2019)

Analysis of technologies such as Artificial Intelligence and Big Data for the smooth transformation towards I5.0 has been done (Özdemir & Hekim, 2018). Supply chain management 5.0 has been evaluated in context with I5.0 where the role of SCM 5.0 and its relation with future economic challenges has been done in the concerned study (Minculete et al., 2021). Critical components have been analyzed for proper implementation of I5.0 in the manufacturing sector where the sensor fusion effectiveness has been evaluated for better implementation of I5.0 concepts(Javaid & Haleem, 2020). Analysis carried out related to gas detection and robust sensor fusion (Rahate et al., 2022) where potential applications and enabling technologies have been analyzed by a survey in context with I5.0. Technologies under consideration were supply chain management, cloud manufacturing, and intelligent healthcare. Human-Robot co-working and cobots(collaborative robots) technologies have been analyzed concerning I5.0 (Demir et al., 2019). Investigative research has been carried out for achieving sustainable reliability-centred maintenance where the fuzzy logic technique has been used to understand the relationship between maintenance and operation phases (Farsi et al., 2021). Advanced manufacturing and Artificial Intelligence have been analyzed in context with I5.0 and the viewpoint discussed which argued that I5.0 technologies will produce more employment than unemployment (Nahavandi, 2019b). Lean Six Sigma (LSS) tools have been analyzed in light of I5.0 (Rahardjo & Wang, 2022.). It has been found that if LSS is embedded in man-oriented disciplines then perfect combinations of improved result environment and human processes can be created.

4.5 Food Industry

The food industry is another important area of application for I5.0 technologies. A model has been proposed related to food manufacturing in the context of I5.0 for small and medium enterprises (Saptaningtyas and Rahayu, 2020.). Society 5.0 has been introduced for involving the customer in the product development process. A product development model has been proposed for food production industries in small and medium enterprises that are facing transformational challenges in adapting to I5.0. Society 5.0 also has been introduced for more customer involvement during the design phase while developing a product. An updated model of the food development cycle has been presented which can enhance customer satisfaction in the food manufacturing sector.

4.6 Medical Applications

I5.0 found considerable application in the precision manufacturing of medical types of equipment. Considering medical applications, not many contributing articles have been found but an article attempted to identify the significance of enabling technologies in the field of orthopaedics. It mentioned that problems such as wrong tool selection, overproduction, and lack of transparency during treatment can be tackled in a better way (Haleem & Javaid, 2019b). Another article explained the expected applications in various medical fields (Haleem & Javaid, 2019a). Major contributed technologies presented in the article was Holography, advanced imaging, 4D MRI, 4D CT, smart sensors, Internet of Everything, Big data, Additive Manufacturing, collaborative robots, and many more with the help of year and location, analysis of many applications can also be done such as sick rate, death, and birth(Rupa et al., 2021). Blockchain can be applied to creating new certificates along with maintaining the existing certificates. Implications and relevance of synthetic biology and bionics were under consideration (Sachsenmeier, 2016). The work explains the timeline starting with recent project works as well as their implications, for instance, signalling molecules, artificial DNA, and many others. The pharmaceutical manufacturing field was under consideration in the context of I5.0 and the article evaluated the solutions as well as hurdles in implementing the enabling technologies of I5.0 (Sharma et al., 2022). Supply chain management was under consideration and barriers have been identified which were arguably decreasing the probability of failure in the implementation process of I5.0. Technological aspects of cobots, curbot, and chip-bot were under analysis after the era of COVID-19.

5. Enabling technologies of Industry 5.0

To produce sufficient and customized deliverables, I5.0 encompasses different enabling technologies such as blockchain, cobots, big data, IoT, digital twins, and edge computing (Maddikunta et al., 2022). Above mentioned technologies drive the I5.0 into a growing product-driven model that put more emphasis on human-machine interaction. To collaborate with humans, advanced systematic machines are designed, and these collaborative efforts drive increased productivity, and which can be termed collaborative automation.

Enabling technologies are those technologies that facilitate the implementation of I5.0. Mentioned below are the technologies that are at the core of I5.0.

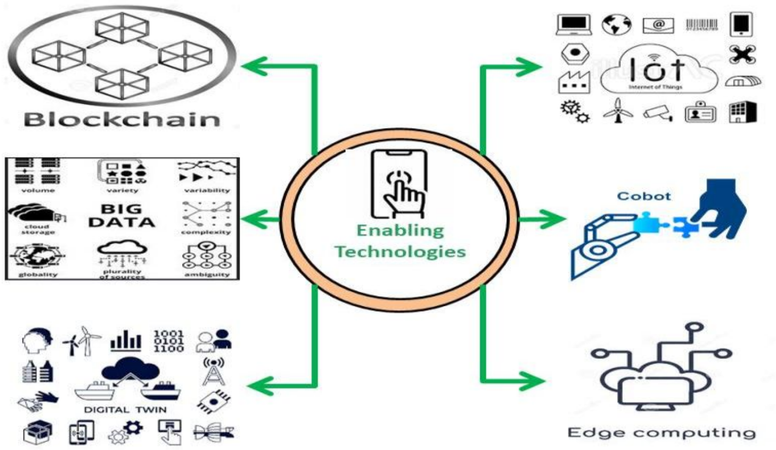

Figure 5: Enabling Technologies *(Source: Authors' own creation)*

5.1 Block Chain

The key highlighted feature of blockchain is decentralization at the managerial level as it can contribute significantly to the upcoming I5.0 (Humayun & Arabia, n.d.). The concept of trust distribution is the key to managerial decentralization. Record keeping through the communication chain helps to secure the data in a better way. The blockchain approach can also help in keeping enhanced safety for the data. The blockchain approach also creates transparent operations as a good creation of digital identity. The compartmental approach helps implement the blockchain in a better way.

5.2 Cobots

Collaborative robots (Cobots) perfectly exemplify the core idea behind I5.0i.e. human-centric approach. Working with robots is essential for humans in the context of automation's latest trends (Maddikunta et al., 2022). Cobots technology is introduced keeping in consideration that the machines with the capability of computation becoming more intelligent owing to fast advancements in AI. Cobots will be the future robots that are primarily made for intensive collaboration with men, which in turn affect the efficiency and capability of humans. Initially, cobots come into the picture in the year of 1996 by Michael Peshking and Edward Colgate at Northwestern University. Collaborative robots primarily work with sensors and their response is very high to detect unpredictability in impacts.

5.3 Big Data

In academia as well as in industries, big data is a key technology of discussion as it presents diversity in the collection of data from multiple sources. Numerous data fetching technique includes big data, for instance, data fusion, data mining, social networking, AI, and ML(Demir et al., 2019). Big data unarguably play a vital role in the transformational journey from Industry 4.0 to Industry 5.0. Big data techniques can be implemented by organizations to target the audience according to their age, sex, gender, and location therefore big data tends to revolutionize the sector of product marketing. Challenging roles such as handling large volumes of data can be eased if data centres, as well as smart systems, collaborate to analyze the real-time data. Big data techniques may provide useful support for maximizing predictability.

5.4 Internet of Things

IoT and related technology such as the Internet of Everything focuses on the interconnection of things, information, process, and people. For exploring unidentified opportunities, IoT can play a vital role. Its significance in the implementation of Industry 5.0 is to provide opportunities for minimizing operational capital through the elimination of possible obstacles in the channel of communication(Alvarez-Aros & Bernal-Torres, 2021). Optimization of the product manufacturing process and waste minimization within the supply chain can be achieved with the proper utilization of IOT and IOE.

5.5 Digital Twins

DT is termed as the process of digital cloning an object or a physical system representation of a huge system, Building structures, and manufacturing units can be easily done through the assistance of DT technology (Mourtzis et al., 2022). The role of DT in the transformation towards I5.0 is to present considerable value to develop customer-centred products in the marketplace. The identification process of technical issues can be rapidly done through the DT technology and therefore DT enabling technology can directly identify technical issues so that solutions can be drawn as soon as possible. DT can also enhance the customer's virtual experience of the actual product and therefore satisfaction level of the customer can be greatly enhanced. Predictive maintenance can also be achieved by the enabling technology of Digital Twins.

5.6 Edge Computing

The ability of Edge computing, generally termed EC is to meet the expectation regarding data protection, response time requirements, battery life constraints as well as latency costs(Maddikunta et al., 2022). EC is a developing computational paradigm where reference is taken from a range of various devices as well as networks. Edge means processing the data closest to the generation point which in turn accelerates the enabling processing with very high intensity, consequently efficient results will produce in a practically very low time frame. EC will enable I5.0 to use standardized software and hardware resources for exchanging information about the concerned industrial field. With proper implementation of EC, storage costs are bound to come down as it reduces the processing and analysis time by identifying the data as soon as possible.

With the proper adaptations of these technologies during the transformational journey towards I5.0, production as well as a customer-customized by-product will improve and therefore satisfy the very basic root cause of I5.0 which is a human-centred approach in collaboration with machine automation.

6. Barriers to executing Industry 5.0 with mitigation actions

Industry 5.0 can enhance the customization of products and services in the context of manufacturing methods. For proper implementation, these barriers need to be addressed carefully. The issues with humans and robots working together must be analyzed and the effects of this collaboration on the manufacturing techniques and hiring process must be analyzed to tackle the concerns in a better way. Apart from that, the ethical concerns related to using artificial technology need to be addressed to avoid possible problems in the successful implementation of I5.0.

6.1 Barriers to Industry 5.0

The I5.0 execution is hindered by different barriers at different levels within the organizations. The barriers to implementing I5.0 are as follows:

6.1.1 Security concerns

Implementation of I5.0 will surely need to address security concerns for instance authentication, availability, integrity as well as auditing concerns. Auditing is considered an important aspect to benchmark the regulations as well as observe the functioning of the system according to the objectives. Proper auditing can find the faults in the functioning and suggest corrective measures timely to prevent future damage to the organization. Authentication is also a major issue in the process of implementation. To maintain the belief in the system, authentication of all divisions is inevitable, for instance, communication nodes, fog nodes, machines, and IOT nodes. The mechanism of authentication needs to be measurable for connecting numerous devices, the resistance of quantum, and at the same time lighter in weight for proper placing IOT nodes (Maddikunta et al., 2022). Integrity is also a major issue regarding the security of data for implementation of Industry 5.0 because the vigilant data and guiding commands need to be sent to external networks so the integrity concern must not halt the overall efficiency of the system.

6.1.2 Privacy Issues

Privacy of data is also an important concern because, for proper collaboration of all systems including machines, computers, humans, digital infrastructure, and physical infrastructure, information compulsorily be exchanged on the internet and the possibility is there that the data is leaked in the hands of rivals and competitors which is unsafe for proper functioning and growth of the system.

6.1.3 Scalability concerns

Whenever the workload is rearranged for the system, its responsiveness, flexibility, and resilience measurement are termed scalability (Sharma & Kiran, 2020). As the interconnected data will grow exponentially, its expansion can change the loopholes and minor faults will exaggerate and have the potential to create potential concerns, therefore tackling the scalability concern is unarguably important during the transformational journey from I4.0 to I5.0.

6.1.4 Regulatory Issues

Implementation of I5.0 includes proper guidelines and policies to be complying with regulation and laws because the objective of I5.0 is the collaboration of humans with cobots, necessary laws in context with territorial jurisdiction needs to be followed. Policy updation and its legal effects on the system must be vigilant by the higher management as the new concept brings new challenges in its implementation. Quantum computing and blockchain are the tools that can help to tackle regulatory issues.

6.1.5 Social Issues

It is quite evident that the social system will be significantly affected by I5.0 technologies. Updating the working environment needs time to settle among the workforce and therefore addressing the social issues is equally important for the successful implementation of I5.0 (Leng et al., 2022). Society's ethical and moral issues are also going to play an important role in the approach of the people involved in the process, therefore dedicated planning is required to address the social issues bound to arise in this transformation towards I5.0.

6.1.6 Skilled Manpower

Maintaining the highest efficiency and performing the highest valued work concerning standardization, production, and other aspects, the policy needs to be formed for handling any management, society, or technical issues. Providing skilled manpower has a lot of issues for employees, management, and for the company (Paschek et al., 2019). The major challenge will be the unavailability of proper training staff and monetary hurdles in arranging adequate training to manage the technologies of I5.0. Apart from that some organizations may not have the proper infrastructure to implement the enabling technologies.

6.1.7 Technical Issues

Shifting the focus from total automation to human-centric automation might be a challenge for industries as the technologies for many years are focusing only on eliminating human interference and therefore the industries should be ready to face technical challenges during the implementation of systems for I5.0 (Alvarez-Aros & Bernal-Torres, 2021). Design and Manufacturing of new systems will be a tedious task for designers, programmers, and architects initially because there is very less information available on the internet and it will be very rare to find the complex analysis of running systems based on I5.0 as most the industries are in the transforming phase currently.

6.2 Mitigation of the Barriers

Based on the systematic investigation of the literature, mitigation actions have been suggested These actions will act as guidelines or suggestions for the key decision-makers during the implementation phase of I5.0.

Barrier mitigation action 1: The problem of skilled manpower should be handled by HR and recruiting department while choosing and interviewing potential workforce. In addition, regular training for the ground-level workforce must be conducted to ensure the regulations and to meet the objectives. Apart from that, the training of the manpower needs to be conducted in the virtual mode so that it will not halt the production or process. Virtual reality techniques with the help of Graphical processing units and Artificial Intelligence can transform the complete experience of Virtual training as compared to conventional ones (Leng et al., 2022; Nahavandi, 2019b). Further, the employees must be provided comprehensive training related to different techniques of I5.0, software packages, and technical know-how of I5.0. Moreover, employees should also be given provided hand on practice to realise all sets of technologies in different projects of I5.0.

Barrier mitigation action 2: Continuous awareness among individuals at all levels is the key to avoiding social issues. Regular sessions for the awareness of manpower need to be conducted. In addition, moral and ethical values should be addressed during virtual training sessions so that the complete mindset of individuals is shifted toward the proper implementation of I5.0 systems (Maddikunta et al., 2022; Nahavandi, 2019b).

Barrier mitigation action 3: To tackle the issues of benchmarking and regulations, experts should be consulted at regular intervals and the manager at all levels needs to be completely aware of all concerned policies and processes so that regulatory issues will not be raised when the full-fledged systems are in function (Mukherjee et al., 2023). Different regulations and standards to execute different sets of technologies must be decided at the start of realize of I5.0 so that potential conflicts of interest can be avoided and the accuracy of the outcomes can be assured.

Barrier mitigation action 4: To address security concerns, auditing should be done by highly experienced individuals, and consistent efforts are required in terms of authentication of data and systems (Maddikunta et al., 2022; Mukherjee et al., 2023). In addition, the data related to objectives, goals, targets, and manpower should not be easily available, and technically superior persons are inevitable to tackle security concerns while implementation. Further different cyber security measures and protection measures of blockchain should be used to avoid any alteration or breach of the sensitive dataset.

Barrier mitigation action 5: For the better resolution of technical issues, corrective measures should be taken when systems are functional so that the issues should be addressed in no time and therefore the errors can be identified at the very initial stage. In addition, the quality assurance department should do case studies at regular intervals for peer companies so that similar problems can be identified well on time (Alvarez-Aros & Bernal-Torres, 2021; Maddikunta et al., 2022).

7. Industry 5.0 mapping with Sustainable development goals

I5.0 technologies add or supplement prestigious sustainable development goals (SDGs) to make this planet a better plan to live. The mapping of SDGs with different I5.0 technologies is as follows:

SDG 3: Good Health and Well-Being: Firstly, integration of I5.0 leads to strong collaboration between humans and the latest advanced technologies that lead to the implementation and development of innovative healthcare technologies such as AI-driven diagnostics and wearable healthcare devices. Secondly, a strong emphasis of I5.0 on human-machine collaboration can facilitate adoption personalized medicine approaches because the enormous amount of patients' data when combined with individual genomic information can help in generating unique and personalized treatment plans which satisfy patient's specific needs. Thirdly, integrating the I5.0 technologies can accelerate medical research and drug development methods as AI-generated algorithms can analyse huge amounts of biomedical data and thus it is easy to identify potential drug candidates, which may lead to the discovery of new therapies and treatments. Finally, the prime focus of I5.0 is on human-machine collaboration and it will surely improve workplace health and safety standards because robots and automation take care of dangerous tasks consequently reducing the risk of accidents and injuries. Combinedly, it can be said that although I5.0 is not implemented yet in most of industries worldwide, the technological progress and the integration of machine-human collaboration have a significant potential to impact healthcare and contribute to the achievement of SDG 3 i.e. ensuring good health and well-being for all.

SDG 9: Industry Innovation and Infrastructure: One of the main objectives of I5.0 is to integrate advanced technologies with humans and therefore encourage the development of smart manufacturing processes. Robotics, automation and AI can optimize production lines, can increase efficiency, minimize errors, and therefore leads to enhanced industrial productivity and innovation. Apart from it, improvement in the interconnectedness between various industrial systems is another objective of I5.0 that will lead to continuous communication and data sharing among the entire value chain. This interconnectivity certainly will lead to better coordination, improved supply chain management and more adaptive production processes. Furthermore, adapting I5.0 technologies will surely generate an enormous amount of data from industrial systems and processes and analysing it using big data analytics and AI can provide quality insights for better decision-making that allows industries to identify key areas for innovation and improvement. In addition, with the help of emerging technologies and innovative approaches, I5.0 can contribute to the development of sustainable infrastructure such as creating infrastructure that integrates clean energy solutions and improves resource management. I5.0 also emphasize the collaboration between humans and machines that in turn identify the importance of human skills and creativity along with the use of technology. All the above-mentioned points are in alignment with SDG 9's vision of sustainable industrialization.

***SDG 11: Sustainable cities and communities**:* By integrating technologies such as sensors, IoT devices and data analytics, urban areas can become more responsive and efficient which can lead to optimized energy consumption, better waste management and improvement in transportation systems. Apart from that, I5.0 surely enable better waste management practices by using data-driven systems. Waste-to-energy technologies and improved recycling processes can help cities to reduce waste generation. I5.0 concepts if applied in urban planning by incorporating citizens' data along with feedback, can make cities development more participatory and inclusive. This concept will lead to cities which are suited to the needs of its citizens that in turn contribute to community well-being and social integrity. Furthermore, I5.0 technologies, such as AI-driven predictive models can improve disaster management by analysing data and patterns. By doing this, cities can be better prepared for natural disasters and similar emergencies that will ensure the safety and well-being of their communities. In addition, through innovative construction methods like modular building and 3D printing, I5.0 can help with the challenges of affordable housing in urban areas. Sustainable and efficient housing solutions can contribute to the betterment of communities.

***SDG 12: Responsible consumption and production**:* I5.0 technologies can improve efficiency by combining data analytics and automation for optimizing production processes that can further lead to reduced waste and increased use of recycled materials. Technologies such as IoT and blockchain can improve transparency and traceability within supply chains. It can consequently help businesses and consumers make more informed decisions about the products that ensure responsible sourcing and ethical production practices. Furthermore, I5.0 technologies can enable more sustainable manufacturing procedures by adopting clean technologies and renewable energy sources that lead to lower carbon emissions and therefore a reduced environmental impact of industrial activities. Extended product lifespan can be achieved by I5.0 technologies as it facilitates predictive maintenance and conditional monitoring that leads to timely repair and maintenance and increased lifespan of the product. At last, I5.0 support the growth of shared and collaborative economy models, where assets and resources are shared with many users which can further reduce overall resource consumption and promote responsible consumption.

7.1 Industry 5.0 and Social Sustainability

I5.0 is a return to industrial production but encompassed by an advanced set of ICT technologies to improve socio-environmental sustainability (Østergaard, 2017). It has been argued that by centring humans at the centre of the productions system, aided by COBOT, the industry will not only be able to deliver mass personalize products but also give workers jobs that are more meaningful than factory join has been in well by a century (Haleem & Javaid, 2019). Further, it has also been found that a high level of automation may lead to a total network failure in case of hacking of the network or a socio-political shift of political power. This also fosters the incorporation of the human touch within production facilities to ensure social and environmental sustainability. I5.0 technologies prompt the social perspectives and well-being of the employee working within the industry and the entire supply chain. Human interaction aspects and intervention will make the system more responsive in terms of cognitive and emotional thinking which is helpful to prevent hazards. Further I5.0 practices will bring more harmony to the workplace by comprehending different aspects of learning, ergonomics, and environmentally friendly measures, and introducing different work-friendly measures at the workplace that will pen ultimately lead to the improved organization's social sustainability in the long run.

8. Future Aspects of Review

Because of certain constraints, some viable points remain untouched and need to be addressed in future work in this field. Firstly, Data can be collected through on-site visits or running processes so that challenges and issues can be found from ground-level systems. It will help in the generation of ground for common guidelines for better implementation of enabling technologies. Feedbacks and real-time analysis always provide more clarity on the efficiency of the systems and what are the ground-level challenges to be addressed during implementation. Secondly, an in-depth study on enablers of I5.0 and their proper identification are essential for enlightening the proper pathway of implementation. Subsequently, the work can be carried out that how a particular barrier is related to a specific characteristic of I5.0. These correlations can further be taken care of while working on these barriers/ Furthermore, advanced studies on simulations to test the hypothesis can be done and its comparison should be done with expected results. Various simulation software can be used to test the systems virtually before testing them physically. AI and virtual reality can certainly help in this regard, and they will surely reduce the research and analysis costs of organizations. In addition, it will also help the decision makers to decide on the economical, physical, and technical requirements without starting things on actual grounds. Apart from it, simulations also help in the analysis of various alternatives for doing the same sort of operations. Finally, a comparative analysis of the implementation path of various sectors regarding I5.0 can be done. As the requirements, outcomes, and functionality are completely different in various sectors such as manufacturing and medical fields, therefore, a comparative analysis is also required to explain the implementation pathways for various sectors separately. It will require an analysis of the basic requirements of different sectors and to do desired changes in the basic theoretical concepts according to those requirements.

9. Inferences

In the past few years, discussions and studies are being conducted more frequently regarding the transformation of systems from Industry 4.0 to Industry 5.0. In current work, literature has been reviewed for various concerned industrial sectors such as manufacturing, civil, electronics, computers, and medical applications. Furthermore, barriers during the implementation of I5.0 have been identified and mitigations have been suggested for the barriers. The main barriers identified were security, authentication, privacy, and scalability concerns. Apart from it, skilled manpower, social and technical issues also present significant challenges and need to be addressed. Mitigation actions have been suggested such as proper auditing, regular and continuous benchmarking, and continuous awareness of manpower through regular training by using tools such as virtual reality and graphical processing units. Apart from it, regular case studies have been suggested to forecast common challenges during implementation and proper functionality. In addition, various enabling technologies have been reviewed in the light of available works of literature such as blockchain, IoT, big data, collaborative robots generally termed cobots, digital twins, and edge computing. At last, future perspectives have been suggested to help future researchers in further exploration of I5.0. The main suggestions for future studies are on-site research to get real-time feedback, in-depth study on enablers, simulation, and analysis before actual implementation and comparative analysis of implementation path for various sectors. Concretely, the study will not only help academic researchers but also present a guideline for regulatory bodies and key decision-makers in the managerial hierarchy during various phases of implementing I5.0.

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