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Challenges of the Fifth Industrial Revolution: A Systematic Literature Review

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Abstract

Purpose: The study is intended to describe an overview of Industry 5.0, highlight its difficulties in the current economic environment, and demonstrate how to plan and execute future corporate structures.

Design/Methodology/approach: The authors used a systematic literature review of articles related to Industry 5.0. The Scopus and Web of Science database was used to extract the articles to be reviewed.

Findings: The results show that Industry 5.0 stands for the next phase of industrial transformation, providing viable answers to the ecological and societal problems that Industry 4.0 either failed to address or made worse.

Research Limitations: The study is based only on two databases. Therefore, some articles were left from other databases such as Ebscohost, Proquest, PubMed, etc.

Implication: The difficulties of integrating with current systems can be effectively addressed during deployment.

Originality/Value: The traditional industries have changed to become socially conscious as a result of an increase in emphasis on sustainability and resilience. This article examines the obstacles to Industry 5.0 adoption.

Keywords: Automation, Industry 4.0, Industry 5.0, Robotics, Technology

1. Introduction:

The last ten years have seen the provision of Industry 4.0 to address the flaws within the industry; at last, Industry 5.0 is becoming necessary. Industry 4.0 has limits since smart factories boost corporate productivity. In 2021, the European Commission proposed that the industry in Europe realign its social roles and advance this idea to characterize the coming success of European business (European Commission, 2021). Aligning "the green" and "the digital transitions" to establish an increasingly effective, resilient, and sustainable society and economy is the fifth industrial revolution (European Commission, 2021). By stressing the social function of industry, Industry 5.0 enhances the techno-economic agenda of the Industry 4.0 paradigm (Kagermann et al., 2013). Although the literature offers conflicting accounts of Industry 4.0's advancement across a range of sectors and geographical areas (Ghobakhloo et al., 2021; Ijaz Baig and Yadegaridehkordi, 2023), there are arguments on the fifth industrial revolution's presence (Sindhwani et al., 2022). Values are what propel Industry 5.0, whereas technology is assumed to be the driving force behind Industry 4.0.

An array of frameworks, architectural designs, and models have been created and laid out in earlier studies to help better clarify Industry 4.0's functions and the technologies that underpin it. Industry 5.0 is a phenomenon that has received much less research attention than Industry 4.0 (Breque et al., 2021a; Fatima et al., 2022). Supporters of Industry 5.0 present two opposing viewpoints while elucidating the mechanism underlying this phenomenon. According to the first viewpoint, the workplace of the future will be revolutionized by the unprecedently rapid growth of disruptive technologies like 6 G, AI, and cognitive computing, which will seamlessly integrate people with machines and the surrounding technological environment (Chen and Okada, 2020; Xu, Zhou, et al., 2021). The second viewpoint maintains a comprehensive techno-cultural understanding of the forces driving Industry 5.0 and contends that this phenomenon explicitly tackles two major shortcomings of Industry 4.0: proficiency and technology (Broo et al., 2022; Dautaj and Rossi, 2022). The latter viewpoint, which claims that an eco-friendly, human-centered, and resilient industry should be given priority

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in this phenomenon, has recently gained attention to the European Commission's Industry 5.0 agenda (Breque et al., 2021a). The main obstacles that could prevent the adoption process from occurring must be recognized and assessed to effectively support the creation and execution of I5.0 projects in emerging economies (Karmaker et al., 2023).

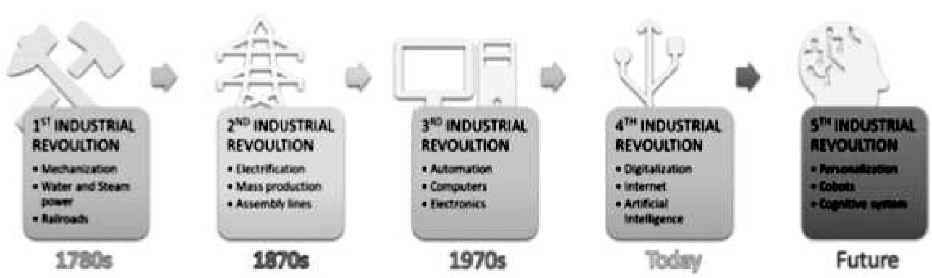
2. History of Industrial Revolutions:

The reshaping of society as a result of technological and technical advancements is known as the Industrial Revolution. Every phase has a gentle transition from one to the next, making it impossible to identify distinct borders between them (Nikishina, 2023). A significant change took place throughout the first industrial revolution in the 18th century, when products were manufactured using machine-manufacturable methods and procedures that had been invented. While a few negative aspects of this revolution included pollution and the time it took to perform the corresponding actions. Industry 1.0 made use of geometry and linear programming (Vinitha et al., 2020). At long last, it had spread to the United States from its beginnings in England in 1760. Industry 1.0 affected several industries, including mining, textile, agriculture, glass, and many more, by signaling a change from a handcraft society to one dominated by machinery (Longo et al., 2020).

Further, the period from 1871 to 1914, represents the second revolution indicating subsequent transformation in the manufacturing sector which made it possible for creative ideas and people to move more quickly. Iron, steel, trains, electricity, paper, petroleum, chemical, marine technology, rubber, cars, applied science, turbines, telecommuting, and contemporary business management were the primary subjects of this revolution (Akundi et al., 2022). Advantages of this revolutionary change include continuous growth, job opportunities, and development in agriculture, and logistics. A few negative aspects of this revolution included pollution and the time it took to perform the corresponding actions. Economic expansion throughout the second revolution has increased corporate productivity, which has led to a spike in joblessness as robots take the place of factory labor (Adel, 2022).

The third industrial revolution was under way in the 1970s consisting mechanization of computers and memory-programmable controls (Adel, 2022). Production in large quantities and the application of integrated circuit chips and digital logic, Smartphones, etc. were the focal points of this specific period (He et al., 2017). Robots, automated industries, renewable energy, and telecommunication are among the innovations of this revolution. The primary problem with Industry 3.0 is that certain situations would make automated systems unusable (Vinitha et al., 2020). Logical controllers, differential equations, and linear programming were the mathematical instruments used in Industry 3.0. There are characteristics shared by all industrial revolutions that enable them to be classified as revolutions rather than just incremental improvements in industry. As Fig. 1 illustrates, the accumulation of a sufficient number of entirely new industrial production techniques is a prerequisite for the formation of each industrial revolution. Consequently, the real economy is developing evolutionarily. The shift from volume to quality in technology is initiated once these developments reach a certain threshold and obtain the requisite development to enable their practical deployment into industrial production (Popkova et al., 2019).

Figure 1.
Stages of Industrial Revolutions



Source: (Raja Santhi and Muthuswamy, 2023)

The term "Industry 4.0" was coined in Germany in 2011(Lattanzio et al., 2022). The advent of Industry 4.0 in the modern era focused on the use of intelligent systems across all industries. Machine learning in the fourth industrial revolution is facilitating the creation of fully automated and artificially intelligent systems capable of operating in unstable conditions (Akundi et al., 2022). This revolution has two drawbacks: it may leave vulnerable cloud data on the cloud, and it lacks fully developed business-specific expert systems. Network theory and optimization techniques are two mathematical tools used by Industry 4.0. Compared to earlier industrial revolutions, this revolution is exceptional and has a variety of unique characteristics. It envisions the complete removal of humans from every aspect of production, complete automation of the manufacturing process, the creation of global industrial chains concurrent with the abolition of detrimental social effects, a shift in the fundamental nature of industrial patents, and the ability to quickly alter the focus of industrial production. Industry 4.0 is facilitated by nine important technologies identified by Boston Consulting Group including big data, cloud computing, simulation, industrial internet of things, cyber security, etc.(Rüßmann et al., 2015).

The phrase "Industry 5.0" first appeared in scholarly works in 2016 (Lattanzio et al., 2022) and Michael Rada is credited with coining the phrase "Industry 5.0" (Rada, 2015). One of the main features of Industry 5.0 is the application of risk-reduction collaborative robots. These robots can perceive, sense, and comprehend the human operator together with the objectives and standards of the job they are carrying out. These robots assist human operators in carrying out tasks by observing and learning from how an individual completes them. Moreover, Industry 5.0 demands artificial intelligence be integrated with human existence to maximize human potential. Industry 5.0 actively uses sophisticated IT innovations; robots, artificial intelligence, Internet of Things for the convenience and well-being of human labor (Skobelev and Borovik, 2017). The progression of revolution from Industry 1.0 to Industry 5.0 is depicted in Figure 1.

3. Research Methods:

Scopus and Web of Science databases were searched to extract the relevant articles. "Industry 5.0", "Fifth Industrial Revolution", "5th Industrial Revolution", and "challenges" were the keywords used in different combinations. Initially, 796 articles were identified, and 655 after removing duplicates. In addition, a hands-on search was made in Google Scholar to find the relevant articles. In this way, 661 articles were identified. The titles and abstracts were screened manually by the authors. Thereafter, the full manuscript was reviewed and this way, 28 articles were eligible for the final review (Fig. 2). No particular timeframe was chosen. The procedure for searching the literature and choosing articles is shown in Figure 2.

4. Industry 5.0 Definitions

There are numerous definitions of the Fifth Industrial Revolution given by different industrialists and scholars. The European Commission has defined Industry 5.0 as the ambition of industries away from productivity and performance and to make a positive social impact by putting workers in the manufacturing process (Raja Santhi and Muthuswamy, 2023). Further, it was recognized that Industry 5.0 is a well-considered idea that takes into account the future of the sector as an adaptable, sustainable, and human-centered manufacturing and production structure (Breque et al., 2021a). Further, building on the idea and methods of Industry 4.0, Industry 5.0 was suggested as a much-needed evolutionary and gradual improvement (Özdemir and Hekim, 2018). The fifth industrial revolution is the Social Smart Factory era, whereby cobots can converse with people (Koch et al., 2017). According to Nahavandi (2019), Industry 5.0 introduces human labor into the manufacturing process. Humans and machines work together to improve process efficiency by harnessing human intelligence and inventiveness.

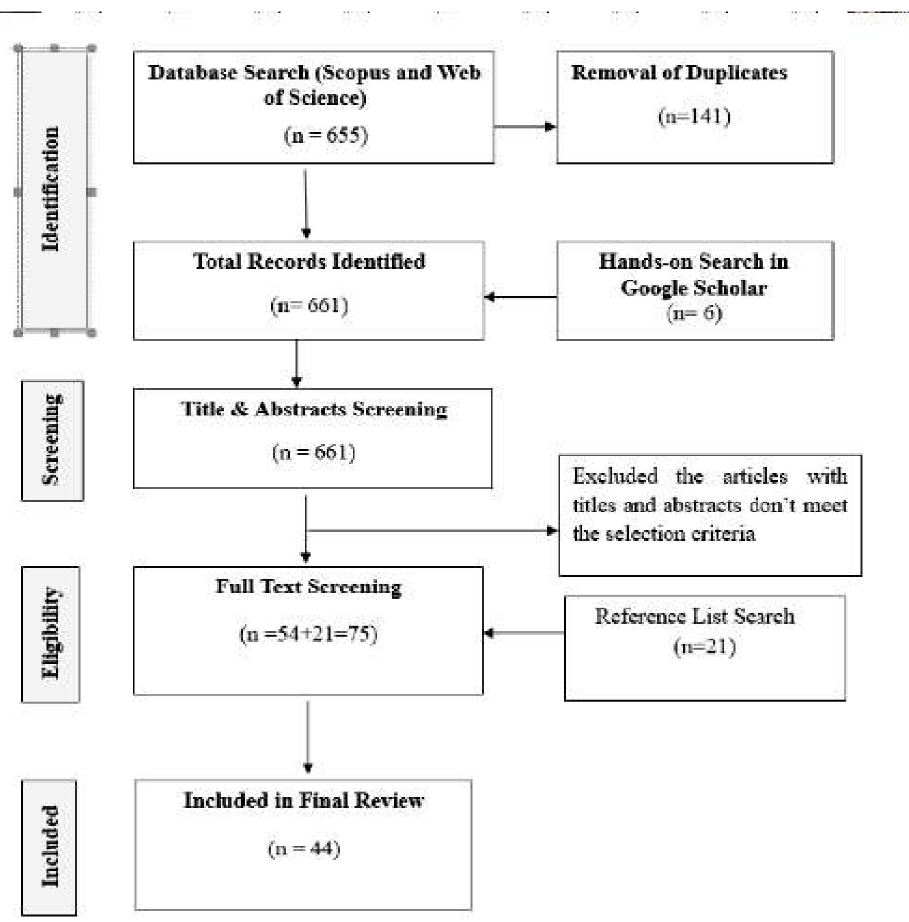


Figure 2.
Articles Selection Process

Further, Rada (2020) defined Industry 5.0 as the first human-led industrial evolution built on the 6R "Recognize, Reconsider, Realize, Reduce, Reuse, and Recycle" tenets of industrial refurbishing, a methodical approach for garbage prevention, and an efficient logistics design to assess living standards, generate creative ideas, and create superior custom products. In addition, Industry 5.0 is a progressive development from Industry 4.0 and represents the forthcoming wave of global governance. Through the separation of the hyper connected automated systems for production and manufacturing, it seeks to develop orthogonal safe exits (Show et al., 2021). In addition, some of the definitions of Industry 5.0 are presented in Table I below:

Table 1.
Definitions of Industry 5.0

Sr. No.	Authors	Definitions
1	(Javaid *et al.*, 2020; Martos *et al.*, 2021)	"The term Industry 5.0 refers to people working with robots and smart machines. It is about robots helping humans work faster by leveraging advanced technologies such as big data analytics"
2	(Imoize *et al.*, 2021)	"Industry 5.0 is termed as the evolution in which man and machine are finding ways to work for improvement means and efficiency of the manufacturing production."
3	(Ocicka and Turek, 2021)	"Industry 5.0 is compelled with various industries technologists, philosophies, and others to focus on the human factors and technologies in the manufacturing systems."
4	(Carayannis *et al.*, 2021; Masood and Sonntag, 2020)	"Industry 5.0 is considered the edge of the smart factory, where it communicates with robots and humans. It uses social networks for communication purposes among humans and electronics components."
5	(Ietto *et al.*, 2022)	"Industry 5.0 added human -centric, sustainable, and resilient concepts to the industrial revolution. It will revolutionize the manufacturing systems worldwide by preventing repetitive tasks from human workers."

Source: (Adel, 2022)

5. Industry 4.0 vs. Industry 5.0:

Industry 5.0 is not entirely new; it has a solid foundation in Industry 4.0. However, Industry 5.0 differs in that its primary objective is to manufacture goods and services for profit while also placing a high priority on the social and environmental elements of manufacturing (Leng, Sha, et al., 2022; Xu, Lu, et al., 2021). Several conversations in academia and industry have been sparked by the fifth industrial revolution (Demir et al., 2019). Numerous theories have been proposed by scholars to explain the achievements of Industry 5.0. Ozdemir and Hekim (2018) described the fifth industrial revolution as a logical progression. In summary, this revolution will support the development of a human-focused, resilient, and environmentally friendly production industry, whereas Industry 4.0 enhances corporate operations (Masoomi et al., 2023). While Industry 5.0 is determined by values, a common perception of Industry 4.0 is that it is a technology-driven sector.

Industry 4.0 and Industry 5.0 can coexist since Industry 5.0 expands and enhances its characteristics (Xu, Lu, et al., 2021). Further, Industry 5.0 is an adjunct to the current Industry 4.0 as it places research and innovation towards the cutting edge of the transition to a sustainable and human-centered European industry (Breque et al., 2021b). Golovianko et al, (2023) observed the idea of Cyber-Physical Systems in the framework of Industry 4.0 evolving into Cyber-Physical-Social Systems in the overall setting of Industry 5.0. Performance would rise if Industry 4.0 and Industry 5.0 coexist successfully without eliminating the need for human labor in the production processes (Breque et al., 2021b).

Industry 4.0 aims to boost mass production and performance by leveraging machine learning to deliver insight across devices and applications (Azeem et al., 2022) while Industry 5.0 focuses on leveraging human specialists' unique ingenuity in combination with robust, intelligent, and precise machinery. Collaboration between robotics and intellectual professionals creates more well-trained positions compared to Industry 4.0. The main goal of Industry 5.0 is huge customization since people will be controlling and guiding robots (Nahavandi, 2019). While the main goal of Industry 5.0 is to increase customer happiness, Industry 4.0 already has robots heavily involved in massive production. In addition, Industry 4.0 focuses on CPS communication, and Industry 5.0 establishes a connection between cobots (Maddikunta et al., 2022).

6. Challenges of Industry 5.0:

Industry 5.0 has numerous promising ideas for the upcoming industrial period; yet, it also encounters certain challenges in the process of driving the industrial revolution (Leng, et al., 2022). It can be stimulating and difficult to see how society is shifting its priorities from economic expansion and employment to improving sustainability and resilience in the industrial process including personnel welfare (Demir et al., 2019). The cognitive capacities needed for the fifth revolution will be far more extensive. The latest advances in artificial intelligence fail to address the difficulties of Industry 5.0, in which fields of knowledge are ambiguous and complicated (Olaizola et al., 2022). IBM's Watson's failure in the healthcare industry serves as a classic illustration of the present constraints of artificial intelligence in fields requiring complicated processes and high analytical sophistication (Advisory Board, 2022). Further, Verma et al., (2022) explained that several complexities are present in using blockchain as a standard technology in Industry 5.0. First is the centralized process of the production control mechanisms in use today that are larger and more intricate to scale for the company's operations. Next, the blockchain network is used to retain and validate every transaction and it takes longer to go through every block in the chain. Because each block size is predetermined, only a certain amount of transactional data may be handled. Numerous transactions take place in real-time industrial settings, which presents scalability challenges and makes the deployment of BC challenging (Verma et al., 2022). Moreover, implementing BC comes at a significant resource expense. Further, Rajesh (2023) stated that it is extremely hard to create value in a socially diverse community since the demands of individuals can vary. As a result, developing social heterogeneity in value for the anticipated advantages of adopting and implementing Industry 5.0 could prove difficult. In addition, the fifth edition of the Industrial Revolution aims to promote environmental and societal values and is expected to increase output utilizing digital technology where evaluating performance can be challenging (Rajesh, 2023). Table II summarizes the key challenges of Industry 5.0 as under:

Table 2.
Summary of Challenges of Industry 5.0:

Competency Skills	(Adel, 2022), (Komar *et al.*, 2022), (Leng, Sha, *et al.*, 2022), (Rajesh, 2023)
Technical Skills	(Adel, 2022), (Leng, Sha, *et al.*, 2022), (Rajesh, 2023)
Human-Machine Collaboration	(Adel, 2022), (Kaasinen *et al.*, 2022), (Mincă et al., 2022), (Rajesh, 2023)
Investments on Training	(Adel, 2022)
Security and Privacy	(Adel, 2022), (Leng, Chen, *et al.*, 2022), (Leng, Sha, *et al.*, 2022), (Verma *et al.*, 2022), (Kankekar *et al.*, 2023), (Maddikunta *et al.*, 2022)
Time-Consuming	(Adel, 2022), (Kaasinen *et al.*, 2022)
Heterogeneity of Systems	(Leng, Sha, *et al.*, 2022)
Managing and Processing of Increasing Data	(Leng, Chen, *et al.*, 2022)
Lack of Management Support	(Kankekar *et al.*, 2023)
Regulations and Management	(Verma *et al.*, 2022), (Leng, Sha, *et al.*, 2022)
Social heterogeneity in terms of values	(Xu, Lu, *et al.*, 2021)

Source: Compiled by Authors

6.1 Skill Gap:
A high level of technological proficiency is demanded for the fifth industrial revolution (Adel, 2022) and it is quite challenging to locate qualified individuals who can accomplish precise man-machine synchronization (Maisiri et al., 2019). Therefore, businesses must put additional efforts into upgrading their present personnel (Ra et al., 2019). According to Kamble et al. (2018), employees frequently do not have the necessary technical skills and norms to adopt Industry 5.0. The use of Industry 5.0 innovations and methods by organizations that lack the necessary technological expertise may impede their capacity to effectively leverage technology. People must acquire competency abilities because, in addition to working with sophisticated robots, they must learn how to collaborate with smart machines (Narvaez Rojas et al., 2021). Retraining and upskilling current staff or hiring highly qualified personnel carries a significant financial risk. Additionally, because most businesses have not yet fully implemented several prospective Industry 5.0 technologies, finding competent labor can be more difficult for developing nations. These disparities may significantly affect how well Industry 5.0 is implemented. Additionally, because personal problem-solving cannot be mechanized, employees must possess strong problem-solving abilities (Dombrowski et al., 2014). Employers who invest in skill development and training for their local workforce can guarantee a trustworthy and permanent team of employees (Aday and Aday, 2020).

6.2 Data Security and Privacy:
One common aspect of Industry 4.0, appears to be the utilization of massive amounts of data enabling system forecasting and management (Jiang et al., 2019). Due to the massive volumes of data needed by Industry 5.0, there may be security risks from data theft and hacking (Ferencz et al., 2021). Moreover, businesses are linked in the era of fully realized big data, and this process will produce a lot of complicated, heterogeneous data that will cause issues with data correctness, consistency, and quality, among other issues. Therefore, to guarantee that confidential information is safeguarded, businesses must modernize their security and privacy measures (Qu et al., 2020). Since integrating the current systems requires the transmission of massive amounts of data, it is important to understand how the data is going to be used before providing it to a stakeholder (Rajesh, 2023). Security and privacy continue to present an additional difficulty in the deployment of Industry 5.0, despite being more difficult with the introduction of Industry 4.0. The use of robotics and artificial intelligence in Industry 5.0 poses risks to the company, thus reliable security is necessary (Li et al., 2019). To solve these issues, a lot of focus needs to be put on developing and putting into place efficient data privacy and security rules and procedures (Gomathi et al., 2023).

6.3 Investment in Training:
Enhancing education and training focuses on delivering employees the abilities and expertise required to collaborate with digital technology during the manufacturing process. This involves instruction in soft skills to cultivate the social and creative intelligence required, in

addition to technical training for operating and maintaining machinery (Pinto et al., 2023). Training employees is necessary for integrating technology with humans (Barata and Kayser, 2023; Leng et al., 2023). Manufacturing businesses are implementing a variety of quality-management technologies to enhance their operational efficiency and attain high quality in their products and processes (Kumar et al., 2018). Zero Defect Manufacturing (ZDM) is the newest method of quality assurance (Psarommatis et al., 2020). ZDM enforces certain new regulations. So engineers and blue-collar workers must receive ZDM technology training. Industry 5.0, on the other hand, requires interdisciplinary and multi-technical knowledge, which increases the need for personnel with the right training and complicates the training process (Leng, Sha, et al., 2022). Also, reskilling laborers for fresh positions comes at a higher expense. It is difficult for businesses to update their production processes to get ready for Industry 5.0 (Adel, 2022). Moreover, several issues have been highlighted in research that prevent organizations from providing their staff with training courses. The cost and amount of work required to complete the training programs are the two most significant of these issues (Cromwell and Kolb, 2004).

6.4 Regulations and Management:

One significant barrier is the centralized process of the industrial control systems in use today. These structures are larger and more intricate to scale for commercial operations. If the central arrangement is conciliated, increased network suspension and processing power emerge from the necessity of redirecting all information (Verma et al., 2022). Officials in a centralized system are fully authorized to confirm the user's transaction. A peer-to-peer linked platform set validates the transaction in a decentralized system. Nonetheless, P2P communication protocols ought to be consistently governed for every kind of application. Creating a single web framework with data communicated via APIs to ensure more control between apps and service endpoints is one potential option.

6.5 Human-Machine Collaboration:

The tenet of I5.0 is that humans and robots should work together instead of against each other to accomplish a shared objective (Sharma et al., 2022). This approach eliminates the requirement for a vast sensory network, computing power, and data storage while combining and enhancing human cognition with machine intelligence to enable endless creativity (Huang et al., 2022). Consequently, human-robot collaboration may lead to several issues if suitable boundaries aren't present. Therefore, precise definitions of a machine and a robot should be included in rules controlling the collaboration of robots and humans (Demir et al., 2019). Industry 5.0 puts human labor again on the manufacturing floor, where workers will collaborate with Cobots. Even if it appears to be a productive method for creating customized items, some concerns about humans and robots working together need to be taken into account. Furthermore, once humans and robots divide the workload, people's fear of losing their employment will be eliminated (Maddikunta et al., 2022). By doing repetitive tasks, cobots will free up human resources to focus entirely on creativity and invention. It will prove better for cobots to support humans rather than the other way around, which could disrupt the current corporate culture of position competitiveness and cause disorder in organizational behavior. This could lead to a variety of issues, including the changing role of human resources, robotics in IT offices, issues concerning ethics, preparing people to face off with autonomous robots, legal problems, mental health issues about making people adopt new working practices, and job dynamics analysis for both cobots and humans (Sheridan, 2016).

6.6 Ethical and Social Challenges:

Job losses and cross-training may occur because Industry 5.0 implementation requires highly qualified laborers. In addition, as machines can do dangerous and monotonous tasks and experienced workers are needed to coordinate and make timely judgments and decisions, there may be ethical concerns over automation and its effects on society. When it comes to job displacement, ethical challenges can have a major detrimental effect on the psychological well-being of staff members, which can then harm the production processes as a whole

(Fossen and Sorgner, 2022). As a result, businesses must pay close attention to the ethical challenges and guarantee that their innovations are sustainable and responsible.

Society will undoubtedly go through several changes as we approach the Industry 5.0 age, which will result in social ideals and acceptance becoming more diverse (Leng, Sha, et al., 2022). In terms of societal ideals, they require time to develop and appropriate policies to direct them. In addition, the shift in society's manufacturing duties from technology-driven to focus on value will damage the chain's overall structure and lead to excessive production, which will have an impact on the value chain's stability. It is now clear that social systems will be significantly impacted by Industry 5.0 development, which will consequently be constrained by several social variables.

6.7 Lack of Infrastructure:

Given its substantial weight in ideal standards, industrial executives must devote considerable resources to establishing technological infrastructure to introduce computerization into current production processes (Moktadir et al., 2018). Industry 5.0 cannot be supported in an inadequate infrastructure because of inadequate funding or ineffective resource allocation. Modern technical infrastructure that offers quick, safe, and dependable services is necessary to guarantee near-real-time access to information (Rüßmann et al., 2015). Once the problem with the technology infrastructure is solved, it will be simple to deal with and resolve additional issues. Once the problem with the technology infrastructure is solved, it will be simple to resolve additional issues. Industry 5.0 necessitates an ICT infrastructure with a fast and dependable internet to share data at an even greater scale as well as quality than current networks (Sayem et al., 2022). Adopting Industry 5.0 may be difficult due to inadequate ICT infrastructure and ambiguous contracts about liability, privacy, and the effects of data loss (Kankekar et al., 2023). The implementation of horizontal, vertical, and end-to-end integration for Industry 5.0 will be problematic in the absence of ICT infrastructure (Xu et al., 2018). As a result, the biggest obstacle to implementing Industry 5.0 is the lack of advanced technology infrastructure.

7. Discussion:

Industry 5.0 plans depict future facilities that are person-centered, robust, and sustainable, with intelligent robots and human operators cooperating in teams. For such groups to adapt to shifting circumstances in their surroundings, they must possess resilience (Kaasinen et al., 2022). Resilience must be demonstrated by dynamic work distribution and team members' adaptability to shifting responsibilities. When an integrated cognitive system is first created and put into use, it consistently evolves together as both machine actors and human actors pick up new talents and skills. Furthermore, as the manufacturing atmosphere shifts, the structure must be flexible and adaptable to meet evolving demands and specifications (Kaasinen et al., 2022).

Drawing from the researchers' definitions, it is evident that Industry 5.0 is the next phase of industrialization rather than an evolution in which humans and robots collaborate. Enabling cobots to learn and deal with a radical transformation of the human brain while collaborating is crucial. This involves combining human intelligence with machine intelligence. According to the review, the regulatory constraints seem to pose the most significant obstacle that must be overcome before implementing Industry 5.0. Since the related technologies are freshly developed and the laws may have been established earlier, as we have previously stated, it is imperative to ensure that the technologies both meet current standards and are ready to support any future expected regulatory challenges (Rajesh, 2023). Further, given that the regulatory challenges may result in additional difficulties when implementing Industry 5.0, it is essential to give it more priority. The second biggest obstacle to Industry 5.0 and associated technology implementation seems to be integration with current systems. In summary, the study's results indicate that an organized framework that businesses and governments can use to get important insights into how to comprehend and handle these problems is necessary for the effective execution of I5.0 projects. Artificial intelligence won't be the only source of innovation in cognition in the future. Rather, the ability of humans and robots to work together will be crucial in overcoming the obstacles that large data-driven, broad thinking will bring. Even though humans will need to learn how to work together in this manner (Olaizola et al., 2022).

8. Conclusion:

In this article, the authors presented how Industry 5.0 has been defined by different scholars. In addition, the authors reviewed the challenges of the fifth industrial revolution. Conclusively, Industry 5.0 roars out of quiet on the verge of this sunup, when ideas like Industry 4.0 and Society 5.0 are fully realized. The goal of the Industry 5.0 idea is to properly balance human and machine efficiency. This is a revolutionary change that provides a solution because it places less focus on technology and assumes that human-machine cooperation is what drives growth.

References

Aday, S. and Aday, M.S. (2020), Impact of COVID-19 on the food supply chain, Food Quality and Safety, Oxford University Press UK, Vol. 4 No. 4, pp. 167-180.

Adel, A. (2022), Future of industry 5.0 in society: human-centric solutions, challenges and prospective research areas, Journal of Cloud Computing, Vol. 11 No. 1, p. 1-15, doi: 10.1186/s13677-022-00314-5.

Advisory Board (2022), 10 years ago, IBM's Watson threatened to disrupt health care. What happened?,https://www.advisory.com/daily-briefing/2021/07/21/ibm-watson#:~:text=The%20project%20had%20aimed%20to,EHR%20system%2C%20among%20other%20issues (accessed on 28 March, 2024).

Akundi, A., Euresti, D., Luna, S., Ankobiah, W., Lopes, A. and Edinbarough, I. (2022), State of Industry 5.0-Analysis and identification of current research trends, Applied System Innovation, MDPI, Vol. 5 No. 1, pp. 1-14.

Azeem, M., Haleem, A. and Javaid, M. (2022), Symbiotic Relationship Between Machine Learning and Industry 4.0: A Review, Journal of Industrial Integration and Management, Vol. 07 No. 03, pp. 401-433, doi: 10.1142/S2424862221300027.

Barata, J. and Kayser, I. (2023), Industry 5.0-Past, present, and near future, Procedia Computer Science, Elsevier, Vol. 219, pp. 778-788.

Breque, M., De Nul, L. and Petridis, A. (2021a), Industry 5.0, R&I Paper Series, European Commission.

Breque, M., De Nul, L. and Petridis, A. (2021b), Industry 5.0: towards a sustainable, human-centric and resilient European industry, Luxembourg, LU: European Commission, Directorate-General for Research and Innovation, Vol. 46.

Broo, D.G., Kaynak, O. and Sait, S.M. (2022), Rethinking engineering education at the age of industry 5.0, Journal of Industrial Information Integration, Elsevier, Vol. 25, pp. 1-8.

Carayannis, E.G., Christodoulou, K., Christodoulou, P., Chatzichristofis, S.A. and Zinonos, Z. (2021), Known unknowns in an era of technological and viral disruptions-implications for theory, policy, and practice, Journal of the Knowledge Economy, Springer, pp. 1-24.

Chen, N. and Okada, M. (2020), Toward 6G internet of things and the convergence with RoF system, IEEE Internet of Things Journal, IEEE, Vol. 8 No. 11, pp. 8719-8733.

Cromwell, S.E. and Kolb, J.A. (2004), An examination of work?environment support factors affecting transfer of supervisory skills training to the workplace, Human Resource Development Quarterly, Vol. 15 No. 4, pp. 449-471, doi: 10.1002/hrdq.1115.

Dautaj, M. and Rossi, M. (2022), Towards a New Society: Solving the Dilemma Between Society 5.0 and Industry 5.0, Canciglieri Junior, Vol. 639, Springer International Publishing, Cham, pp. 523-536, doi: 10.1007/978-3-030-94335-6_37.

Demir, K.A., Döven, G. and Sezen, B. (2019), Industry 5.0 and human-robot co-working, Procedia Computer Science, Elsevier, Vol. 158, pp. 688-695.

Dombrowski, U., Riechel, C. and Evers, M. (2014), Industrie 4.0-Die Rolle des Menschen in der vierten industriellen Revolution, Industrie, Vol. 4, pp. 129-153.

European Commission, D. (2021), Industry 5.0: towards more sustainable, resilient and human-centric industry. https://research-and-innovation.ec.europa.eu/news/all-resear ch-and-innovation-news/industry-50-towards-more-sustainable-resilient-and-human-centric-industry-2021-01-07_en

Fatima, Z., Tanveer, M.H., Waseemullah, Zardari, S., Naz, L.F., Khadim, H., Ahmed, N., et al. (2022), Production plant and warehouse automation with IoT and industry 5.0, Applied Sciences, MDPI, Vol. 12 No. 4, pp. 1-34.

Ferencz, K., Domokos, J. and Kovacs, L. (2021), Review of industry 4.0 security challenges, 2021 IEEE 15th International Symposium on Applied Computational Intelligence and Informatics (SACI), IEEE, pp. 245-248.

Fossen, F.M. and Sorgner, A. (2022), New digital technologies and heterogeneous wage and employment dynamics in the United States: Evidence from individual-level data, Technological Forecasting and Social Change, Elsevier, Vol. 175, p. 121381.

Ghobakhloo, M., Fathi, M., Iranmanesh, M., Maroufkhani, P. and Morales, M.E. (2021), Industry 4.0 ten years on: A bibliometric and systematic review of concepts, sustainability value drivers, and success determinants, Journal of Cleaner Production, Vol. 302, p. 127052, doi: 10.1016/j.jclepro.2021.127052.

Golovianko, M., Terziyan, V., Branytskyi, V. and Malyk, D. (2023), Industry 4.0 vs. Industry 5.0: co-existence, Transition, or a Hybrid, Procedia Computer Science, Elsevier, Vol. 217, pp. 102-113.

Gomathi, L., Mishra, A.K. and Tyagi, A.K. (2023), Industry 5.0 for Healthcare 5.0: Opportunities, Challenges and Future Research Possibilities, 2023 7th International Conference on Trends in Electronics and Informatics (ICOEI), IEEE, pp. 204-213.

He, D., Ma, M., Zeadally, S., Kumar, N. and Liang, K. (2017), Certificateless public key authenticated encryption with keyword search for industrial internet of things, IEEE Transactions on Industrial Informatics, IEEE, Vol. 14 No. 8, pp. 3618-3627.

Huang, S., Wang, B., Li, X., Zheng, P., Mourtzis, D. and Wang, L. (2022), Industry 5.0 and Society 5.0-Comparison, complementation and co-evolution, Journal of Manufacturing Systems, Elsevier, Vol. 64, pp. 424-428.

Ietto, B., Ancillai, C., Sabatini, A., Carayannis, E.G. and Gregori, G.L. (2022), The role of external actors in SMEs' human-centered industry 4.0 adoption: an empirical perspective on Italian competence centers, IEEE Transactions on Engineering Management, IEEE.

Ijaz Baig, M. and Yadegaridehkordi, E. (2023), Exploring moderating effects of industry 4.0 adoption on sustainable performance of Malaysian manufacturing organizations, Journal of Industrial and Production Engineering, Vol. 40 No. 4, pp. 271-286, doi: 10.1080/21681015.2023.2190766.

Imoize, A.L., Adedeji, O., Tandiya, N. and Shetty, S. (2021), 6G enabled smart infrastructure for sustainable society: Opportunities, challenges, and research roadmap, Sensors, MDPI, Vol. 21 No. 5, p. 1709.

Javaid, M., Haleem, A., Singh, R.P., Haq, M.I.U., Raina, A. and Suman, R. (2020), Industry 5.0: Potential applications in COVID-19, Journal of industrial integration and management, Vol. 05 No. 04, pp. 507-530, doi: 10.1142/S2424862220500220.

Jiang, D., Wang, Y., Lv, Z., Qi, S. and Singh, S. (2019), Big data analysis based network behavior insight of cellular networks for industry 4.0 applications, IEEE Transactions on Industrial Informatics, IEEE, Vol. 16 No. 2, pp. 1310-1320.

Kamble, S.S., Gunasekaran, A. and Gawankar, S.A. (2020), Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications, International Journal of Production Economics, Elsevier, Vol. 219, pp. 179-194.

Kaasinen, E., Anttila, A.-H., Heikkilä, P., Laarni, J., Koskinen, H. and Väätänen, A. (2022), Smooth and resilient human-machine teamwork as an Industry 5.0 design challenge, Sustainability, MDPI, Vol. 14 No. 5, pp. 1-20.

Kagermann, H., Wahlster, W. and Helbig, J. (2013), Recommendations for implementing the strategic initiative INDUSTRIE 4.0, Final Report of the Industrie, Vol. 4 No. 0, p. 82.

Kankekar, S.S., Dadwal, S.S. and Ali, A. (2023), Investigating the factors, challenges, and role of stakeholders in implementing industry 5.0 and its impact on supply chain operations: A study of the global agri-food supply chain, Opportunities and Challenges of Business 5.0 in Emerging Markets, IGI Global, pp. 124-150.

Karmaker, C.L., Bari, A.M., Anam, M.Z., Ahmed, T., Ali, S.M., de Jesus Pacheco, D.A. and Moktadir, M.A. (2023), Industry 5.0 challenges for post-pandemic supply chain sustainability in an emerging economy, International Journal of Production Economics, Elsevier, Vol. 258, pp. 1-12.

Koch, P.J., van Amstel, M.K., D?bska, P., Thormann, M.A., Tetzlaff, A.J., Bøgh, S. and Chrysostomou, D. (2017), A skill-based robot co-worker for industrial maintenance tasks, Procedia Manufacturing, Elsevier, Vol. 11, pp. 83-90.

Komar, J., Pfleger-Landthaler, A. and Rabel, B. (2022), Discovering information inefficiencies in manufacturing processes with modified value stream mapping: An analysis approach for facing the challenges of Industry 5.0, 2022 8th International Conference on Computer Technology Applications, presented at the ICCTA 2022: 2022 8th International Conference on Computer Technology Applications, ACM, Kapfenberg Austria, pp. 263-267, doi: 10.1145/3543712.3543738.

Kumar, P., Maiti, J. and Gunasekaran, A. (2018), Impact of quality management systems on firm performance, International Journal of Quality & Reliability Management, Emerald Publishing Limited, Vol. 35 No. 5, pp. 1034-1059.

Lattanzio, S., Goh, Y.M., Houghton, R., Garcia Lazaro, A. and Newnes, L. (2022), European union conceptualisation of industry 5.0: Opportunities and challenges for transdisciplinary engineering, Advances in Transdisciplinary Engineering, IOS Press, doi: 10.3233/ATDE220705.

Leng, J., Chen, Z., Huang, Z., Zhu, X., Su, H., Lin, Z. and Zhang, D. (2022), Secure blockchain middleware for decentralized iiot towards industry 5.0: A review of architecture, enablers, challenges, and directions, Machines, MDPI, Vol. 10 No. 10, pp. 1-32.

Leng, J., Sha, W., Wang, B., Zheng, P., Zhuang, C., Liu, Q., Wuest, T., et al. (2022), Industry 5.0: Prospect and retrospect, Journal of Manufacturing Systems, Elsevier, Vol. 65, pp. 279-295.

Leng, J., Zhong, Y., Lin, Z., Xu, K., Mourtzis, D., Zhou, X., Zheng, P., et al. (2023), Towards resilience in Industry 5.0: A decentralized autonomous manufacturing paradigm, Journal of Manufacturing Systems, Elsevier, Vol. 71, pp. 95-114.

Li, B., Boiarkina, I., Yu, W., Huang, H.M., Munir, T., Wang, G.Q. and Young, B.R. (2019), Phosphorous recovery through struvite crystallization: Challenges for future design, Science of the Total Environment, Elsevier, Vol. 648, pp. 1244-1256.

Longo, F., Padovano, A. and Umbrello, S. (2020), Value-oriented and ethical technology engineering in industry 5.0: A human-centric perspective for the design of the factory of the future, Applied Sciences, MDPI, Vol. 10 No. 12, pp. 1-25.

Maddikunta, P.K.R., Pham, Q.-V., B, P., Deepa, N., Dev, K., Gadekallu, T.R., Ruby, R., et al. (2022), Industry 5.0: A survey on enabling technologies and potential applications, Journal of Industrial Information Integration, Vol. 26, p. 100257, doi: 10.1016/j.jii.2021.100257.

Maisiri, W., Darwish, H. and Van Dyk, L. (2019), An investigation of industry 4.0 skills requirements, South African Journal of Industrial Engineering, Vol. 30 No. 3, doi: 10.7166/30-3-2230.

Martos, V., Ahmad, A., Cartujo, P. and Ordoñez, J. (2021), Ensuring agricultural sustainability through remote sensing in the era of agriculture 5.0, Applied Sciences, MDPI, Vol. 11 No. 13, p. 5911.

Masood, T. and Sonntag, P. (2020), Industry 4.0: Adoption challenges and benefits for SMEs, Computers in Industry, Elsevier, Vol. 121, p. 103261.

Moktadir, M.A., Ali, S.M., Kusi-Sarpong, S. and Shaikh, M.A.A. (2018), Assessing challenges for implementing Industry 4.0: Implications for process safety and environmental protection, Process Safety and Environmental Protection, Elsevier, Vol. 117, pp. 730-741.

Nahavandi, S. (2019), Industry 5.0-A human-centric solution, Sustainability, Multidisciplinary Digital Publishing Institute, Vol. 11 No. 16, p. 4371.

Narvaez Rojas, C., Alomia Peñafiel, G.A., Loaiza Buitrago, D.F. and Tavera Romero, C.A. (2021), Society 5.0: A Japanese concept for a superintelligent society, Sustainability, MDPI, Vol. 13 No. 12, p. 6567.

Nikishina, L.B. (2023), Industry 4.0: history of emergence, development, prospects of transformation into Industry 5.0, E3S Web of Conferences, Vol. 458, EDP Sciences, p. 06023.

Nimawat, D. and Gidwani, B.D. (2021), Identification of cause and effect relationships among barriers of Industry 4.0 using decision-making trial and evaluation laboratory method, Benchmarking: An International Journal, Emerald Publishing Limited, Vol. 28 No. 8, pp. 2407-2431.

Ocicka, B. and Turek, J. (2021), Supply chain sustainability risk management in a digitally VUCA changing world, The Economics of Sustainable Transformation, Routledge, pp. 167-190.

Olaizola, I.G., Quartulli, M., Garcia, A. and Barandiaran, I. (2022), Artificial Intelligence from Industry 5.0 perspective: Is the technology ready to meet the challenge?, Proceedings http://Ceur-Ws. Org ISSN, Vol. 1613, p. 0073.

Özdemir, V. and Hekim, N. (2018), Birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, 'The Internet of Things' and Next-Generation Technology Policy, OMICS: A Journal of Integrative Biology, Vol. 22 No. 1, pp. 65-76, doi: 10.1089/omi.2017.0194.

Pinto, R., Pinheiro, J., Gonçalves, G. and Ribeiro, A. (2023), Towards Industry 5.0: A Capacitation Approach for Upskilling and Technology Transfer, Distributed Computing and Artificial Intelligence, Special Sessions I, 20th International Conference, Springer Nature Switzerland, Cham, pp. 342-351, doi: 10.1007/978-3-031-38318-2_34.

Popkova, E.G., Ragulina, Y.V. and Bogoviz, A.V. (2019), Fundamental Differences of Transition to Industry 4.0 from Previous Industrial Revolutions, Industry 4.0: Industrial Revolution of the 21st Century, Vol. 169, Springer International Publishing, Cham, pp. 21-29, doi: 10.1007/978-3-319-94310-7_3.

Psarommatis, F., May, G., Dreyfus, P.-A. and Kiritsis, D. (2020), Zero defect manufacturing: state-of-the-art review, shortcomings and future directions in research, International Journal of Production Research, Vol. 58 No. 1, pp. 1-17, doi: 10.1080/00207543.2019.1605228.

Qu, Y., Pokhrel, S.R., Garg, S., Gao, L. and Xiang, Y. (2020), A blockchained federated learning framework for cognitive computing in industry 4.0 networks, IEEE Transactions on Industrial Informatics, IEEE, Vol. 17 No. 4, pp. 2964-2973.

Ra, S., Shrestha, U., Khatiwada, S., Yoon, S.W. and Kwon, K. (2019), The rise of technology and impact on skills, International Journal of Training Research, Vol. 17 No. sup1, pp. 26-40, doi: 10.1080/14480220.2019.1629727.

Rada, M. (2015), Industry 5.0-from virtual to physical, https://www.linkedin.com/pulse/industry-50-from-virtual-physical-michael-rada/ (accessed on 20 March 2024).

Rada, M. (2020), Industry 5.0 definition, https://michael-rada.medium.com/ industry-5-0-definition-6a2f9922dc48 (accessed on 20 March 2024).

Raja Santhi, A. and Muthuswamy, P. (2023), Industry 5.0 or industry 4.0S? Introduction to industry 4.0 and a peek into the prospective industry 5.0 technologies, International Journal on Interactive Design and Manufacturing, Vol. 17 No. 2, pp. 947-979, doi: 10.1007/s12008-023-01217-8.

Rajesh, R. (2023), Industry 5.0: analyzing the challenges in implementation using grey influence analysis, Journal of Enterprise Information Management, Emerald Publishing Limited, Vol. 36 No. 5, pp. 1349-1371.

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P. and Harnisch, M. (2015), Industry 4.0: The future of productivity and growth in manufacturing industries, Boston Consulting Group, Boston, MA, USA:, Vol. 9 No. 1, pp. 54-89.

Sagi, V. and Gokarn, S. (2023), Determinants of reduction of food loss and waste in Indian agri-food supply chains for ensuring food security: A multi-stakeholder perspective, Waste Management & Research: The Journal for a Sustainable Circular Economy, Vol. 41 No. 3, pp. 575-584, doi: 10.1177/0734242X221126421.

Sayem, A., Biswas, P.K., Khan, M.M.A., Romoli, L. and Dalle Mura, M. (2022), Critical barriers to industry 4.0 adoption in manufacturing organizations and their mitigation strategies, Journal of Manufacturing and Materials Processing, MDPI, Vol. 6 No. 6, p. 136.

Sharma, M., Sehrawat, R., Luthra, S., Daim, T. and Bakry, D. (2022), Moving towards industry 5.0 in the pharmaceutical manufacturing sector: challenges and solutions for Germany, Transactions on Engineering Management, IEEE.

Sheridan, T.B. (2016), Human-Robot Interaction: Status and Challenges, Human Factors, SAGE Publications Inc, Vol. 58 No. 4, pp. 525-532, doi: 10.1177/0018720816644364.

Show, P.L., Chew, K.W. and Ling, T.C. (2021), The Prospect of Industry 5.0 in Biomanufacturing, CRC Press.

Sindhwani, R., Afridi, S., Kumar, A., Banaitis, A., Luthra, S. and Singh, P.L. (2022), Can industry 5.0 revolutionize the wave of resilience and social value creation? A multi-criteria framework to analyze enablers, Technology in Society, Vol. 68, p. 101887, doi: 10.1016/j.techsoc.2022.101887.

Skobelev, P.O. and Borovik, S.Y. (2017), On the way from Industry 4.0 to Industry 5.0: From digital manufacturing to digital society, Industry 4.0, Scientific Technical Union of Mechanical Engineering" Industry 4.0", Vol. 2 No. 6, pp. 307-311.

Verma, A., Bhattacharya, P., Madhani, N., Trivedi, C., Bhushan, B., Tanwar, S., Sharma, G., et al. (2022), Blockchain for industry 5.0: Vision, opportunities, key enablers, and future directions, Ieee Access, IEEE, Vol. 10, pp. 69160-69199.

Vinitha, K., Prabhu, R.A., Bhaskar, R. and Hariharan, R. (2020), Review on industrial mathematics and materials at Industry 1.0 to Industry 4.0, Materials Today: Proceedings, Elsevier, Vol. 33, pp. 3956-3960.

Xu, L., Zhou, X., Tao, Y., Yu, X., Yu, M. and Khan, F. (2021), Af relaying secrecy performance prediction for 6g mobile communication networks in industry 5.0, IEEE Transactions on Industrial Informatics, IEEE, Vol. 18 No. 8, pp. 5485-5493.

Xu, X., Lu, Y., Vogel-Heuser, B. and Wang, L. (2021), Industry 4.0 and Industry 5.0-Inception, conception and perception, Journal of Manufacturing Systems, Elsevier, Vol. 61, pp. 530-535.

Xu, L.D., Xu, E.L. and Li, L. (2018), Industry 4.0: state of the art and future trends, International Journal of Production Research, Vol. 56 No. 8, pp. 2941-2962, doi: 10.1080/00https://talentcentral.eu.shl.com/player/link/b34063d3352448bfaff26149b094acf0207543.2018.1444806.