FACTA UNIVERSITATIS
Series: **Mechanical Engineering** Vol. 21, Nº 3, Special Issue, 2023, pp. 405 - 432
https://doi.org/10.22190/FUME230616020D

Original scientific paper

INVESTIGATION OF INDUSTRY 5.0 HURDLES AND THEIR MITIGATION TACTICS IN EMERGING ECONOMIES BY TODIM ARITHMETIC AND GEOMETRIC AGGREGATION OPERATORS IN SINGLE VALUE NEUTROSOPHIC ENVIRONMENT

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Abstract. *Industry 5.0 acceptance is accelerating, but research is still in its infancy, and existing research covers a small subset of context-specific obstacles. This study aims to enumerate all potential obstacles, quantitatively rank them, and assess interdependencies at the organizational level for Industry 5.0 adoption. To achieve this, we thoroughly review the literature, identify obstacles, and investigate causal relationships using a multi-criteria decision-making approach called single value Neutrosophic TODIM. Single-valued Neutrosophic sets (SVNS) ensembles are employed in a real-world setting to deal with uncertainty and indeterminacy. The suggested strategy enables the experts to conduct group decision-making by focusing on ranking the smaller collection of criterion values and the comparison with the decision-making trial and evaluation laboratory method (DEMATEL). According to the findings, the most significant hurdles are expenses and the funding system, capacity scalability, upskilling, and reskilling of human labor. As a result, a comfortable atmosphere is produced for decision-making, enabling the experts to handle an acceptable amount of data while still making choices.*

Key words: *Industry 5.0, Risk mitigation, Neutrosophic sets, Aggregation operators, TODIM, DEMATEL*

Received: June 16, 2023 / Accepted July 29, 2023
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1. INTRODUCTION

A special case of a Neutrosophic set known as a single-valued Neutrosophic set (SVNS) is one in which the membership functions for truth, indeterminacy, and falsehood all fall inside the standard interval [0, 1]. Single-valued Neutrosophic sets (SVNS) may effectively and flexibly handle indeterminate and inconformity information in addition to representing imperfect information in the real decision system. They have been proposed recently and are a subclass of Neutrosophic sets. Using single-valued Neutrosophic sets to address challenges involving several factors for making decisions is a crucial application. Utilizing human expertise in conjunction with machines to deliver results in the most effective way is the major goal of Industry 5.0. This integrates human-machine cooperation, might have an influence on manufacturing companies [1]. They could use the efficiency and development of robots in tandem with human intellect to make well-understood judgements and handle extraordinary situations at the same time. Industry 4.0 focuses on digitization and linked automation, whereas Industry 5.0 is the upcoming new technology that focuses on the interaction between humans and machines to improve customer engagement [2]. Managers also believe that implementing Industry 5.0 may lead to expense savings, increased efficiency, mass customization, and improved operational overall effectiveness [2]. Many businesses are attempting to implement Industry 5.0 to reap the benefits of its advantages. For example, to handle the Industrial 5.0 revolution, Unity Twin Inc. is considering implementing the Smart Industrial Software Suite. Even though the COVID-19 pandemic has considerably accelerated human-digital tool and technology cooperation and fundamentally altered the nature of employment in the digital age, many sectors of the economy of growing nations should adopt new industrial advancement like Industry 5.0 [3]. Even though the COVID-19 pandemic has considerably accelerated human-digital tool and technology cooperation and fundamentally altered the nature of employment in the digital age, many sectors of the economy of growing nations should adopt new industrial advancement like Industry 5.0 [3]. This restraint or absence of a suitable path to address the acquisition hurdles results in delayed growth and progress. We want to create a theoretical structure that will help executives get beyond the obstacles to implementing Industry 5.0 while taking this goal into account [4]. Several nations' gross domestic products are greatly boosted by the manufacturing and construction sectors (GDP). Development projects may be seen as a plan manufacturing company while the goods in the sector are often bigger in size. Manufacturing (constructing) ships and aero planes disturbs the distinction between the two industries. The obstacles confronted by the decision-maker when choosing good equipment to work in a manufacturing process or a building project are essentially the same. For many manufacturing and construction companies, choosing the best machine has lately emerged as a crucial issue in decision-making to gain a strategic edge for existence in the international marketplace [5].

Poor technology choice choices have a detrimental effect on user satisfaction by raising quality and maintenance expenses and reducing return on investments. Decision-makers must have the requisite skills and expertise since technology acquisition is a labor-intensive and challenging procedure. Scientists have developed methods to assist decision-makers in response to evaluating the technology selection challenge. The statistical model-based sensible decision sustains approaches offer a comprehensive strategy that makes use of the knowledge already in place and, in addition, provides a glimpse that can aid the decision-maker in analyzing the decisions that are made consequently [5]. It is difficult to create a decision - making system for choosing an appropriate technology. It entails selecting from a wide selection of other technologies that are offered on the market. A construction or manufacturing company that is focused on making a profit would also like to reduce the cost of a machine. Yet, choosing only one price might lead to poor judgements by ignoring several elements that may be just as significant as price. Technical, environmental, logistical, and ergonomic considerations might all be included. Due to these factors, the decision support models employed for machine selection adhere to an MCDM framework [5].

The manufacturing techniques and procedures used by SMEs need to be reviewed, and they must establish an environment created by combining the most recent manufacturing techniques and administrative procedures [6]. The use of new or advanced manufacturing technology (AMT) has been seen as a potential means of increasing manufacturing companies' productivity and reducing their expenses. There are problems with the efficient use of these technologies, despite efforts to define and highlight the advantages and contributions of technology for SMEs. AMT design, setup, and challenges may make it difficult for SMEs to profit from new technology [7]. The performance of businesses adopting AMT is not just dependent on whether the technology used is cutting edge or not. While technology itself has not directly affected how effectively AMTs operate in the workplace, implementation quality is a key consideration [8].

To tackle various decision-making issues and consider the decision maker's (DM) cognitive behavior during the decision-making process in an unstable world, fuzzy TODIM methods have been employed widely and successfully. The advancement of techniques to improve the management of complex efficiency and decision-making factors involving non-probabilistic insecurity is one way to go about this [9]. This is done with the intention of understanding, developing, and using fuzzy technologies in areas like economics, technology, management, and systemic problems. Fuzzy analysis is a technique used in many fields, including engineering, to solve problems involving doubt and ambiguity [9]. It has uses in manufacturing, management, and decision-making issues. The fuzzy set ideas have a great opportunity for implementation to decision-making issues because they include specific modelling properties that are specific modifications of crisp and fuzzy relations, respectively [10]. Fuzzy logic can appear in management and decision-making processes with implications for manufacturing, where it is used as a model to assess the effectiveness of modern production systems.

Industry 5.0 acceptance is accelerating, but research is still in its infancy, especially when it comes to underdeveloped nations. Studies already published only look at a small subset of context-specific obstacles. The objective is to outline all potential obstacles to Industry 5.0 adoption, rank them empirically, and assess interdependencies at the organizational level. To achieve this, we perform a thorough assessment of the relevant literature, gather opinions from experts, identify obstacles, and explore causal links using a multi-criteria decision-making process called the Decision-Making Trial and Evaluation Laboratory Method (DEMATEL). According to the findings, the most significant hurdles are those related to expenses and the funding system, capacity scalability, upskilling, and reskilling of human labor. Finally, taking into consideration expert advice, we offer a thorough explanation of how we used the "Green, Resilient and Inclusive Development" (GRID) framework to identify appropriate ways to overcome the various constraints we had identified. Through the identification and modelling of hurdles, this study advances the study of Industry 5.0, and its conclusions can be utilized by policymakers or other key stakeholders to formulate and priorities initiatives to speed up Industry 5.0 in organizations.

2. LITERATURE REVIEW

We gather and offer the relevant research in this section. This section examines Industry 5.0 to know its theoretical definition, breadth, prospects, and acceptance as well as the barriers scientists have identified that might prevent its effective execution in a developing country.

While Industry 5.0 is still a developing concept that has not reached its pinnacle [11], there are a number of concepts offered by scientists and industry experts, including the following; Industry 5.0 intends to combine the intellectual and decision-making strengths of humans with the synergistic advantages of devices; Industry 5.0 is expected to be the new industrialization with human involvement; and Industry 5.0 is derived on the idea of the 6 R's, which are Recognize, Reconsider, Realize, Reduce [12]. Industry 5.0 entails the methodical removal of waste, the assurance of high-quality, highly tailored goods, and the integration of human elements with business, technology, and technical features [13]. Fig. 1 shows the evaluation of the industry. The foundation of Industry 5.0 is efficiency, durability, and human-robot cooperation, but it also encompasses a wide range of cutting-edge innovations which have their origins in Industry 4.0 [14].

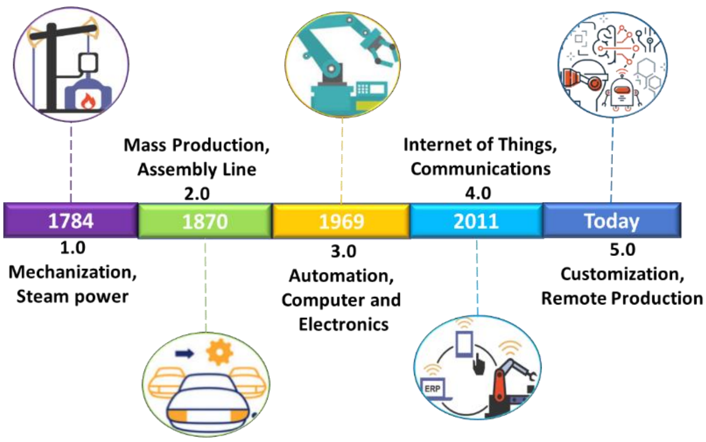


Fig. 1 Evolution of industries from 1.0 to 5.0

For a comprehensive list of advanced technologies, see Fig. 2. In Fig. 2, Industry 5.0 represents the convergence of several advanced technologies that are revolutionizing various sectors. Robotics, blockchain, 5G/6G, big data, AI, and IoT play integral roles in this transformation. Security systems ensure the protection of critical assets and data. Robots collaborate with humans, leveraging their strengths and automating complex tasks. Blockchain technology provides secure and transparent transactions, eliminating intermediaries and enhancing trust. The high-speed connectivity of 5G/6G enables seamless communication and real-time control of industrial processes. Big data analytics extract valuable insights from vast amounts of information, facilitating data-driven decision-making. AI empowers machines with cognitive capabilities, enabling intelligent automation and optimization. IoT connects devices, sensors, and machines, enabling real-time monitoring, predictive maintenance, and enhanced collaboration. Collectively, these technologies revolutionize industries, driving efficiency, productivity, and innovation. Industry 5.0 empowers humans to focus on creativity, problem-solving, and decision-making, while machines handle repetitive tasks. It fosters a symbiotic relationship between humans and technology, resulting in improved processes, personalized experiences, and sustainable growth. Industry 5.0 represents a new era where advanced technologies amplify human potential, reshape industries, and pave the way for a more connected and intelligent future.

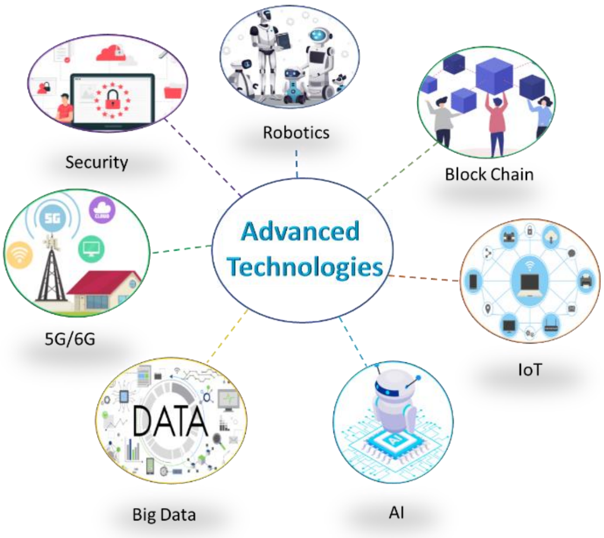


Fig. 2 Advanced technologies of Industry 5.0

Industry 4.0 was first mentioned more than ten years ago in 2011, but studies on Industry 5.0 have just recently gathered traction. Industry 5.0 depends on the principles and ideas of Industry 4.0 in a more comprehensive and futuristic way [11]. Over the past five years, academic studies on Industry 5.0 have irregularly started in various parts of the world [15]. Given that Industry 5.0's central tenet is centered on human-technology and man-machine cooperation, this makes sense [16]. The IoT, digital and mixed technology, robotic driverless cars, cryptocurrency, and intelligent machines are some major topics under the heading of technical elements [17]. Research regarding anticipating the future of employment and learning, particularly their interconnection and the employee development plan for an integrated industry, also included human-centric topics shown in Fig. 3 [18]. Additionally, we cited research that combined technological and human factors, focusing on issues like future human-robot cooperation capabilities and human engagement in industrial technologies [19]. Fig. 3 illustrates the opportunities, limitations and future of Industry 5.0. Industry 5.0, the next industrial revolution, presents a range of opportunities and limitations as well as a promising future. Opportunities lie in the areas of smart infrastructure, clean energy, intelligent transport, and binaural beats. Smart infrastructure utilizes technology to enhance efficiency, sustainability, and resilience in areas like energy management and traffic flow. Clean energy harnesses renewable sources for sustainable power generation. Intelligent transport utilizes technology for safer and more convenient transportation. Binaural beats, sound waves played at different frequencies in each ear, offer benefits such as relaxation and improved focus.

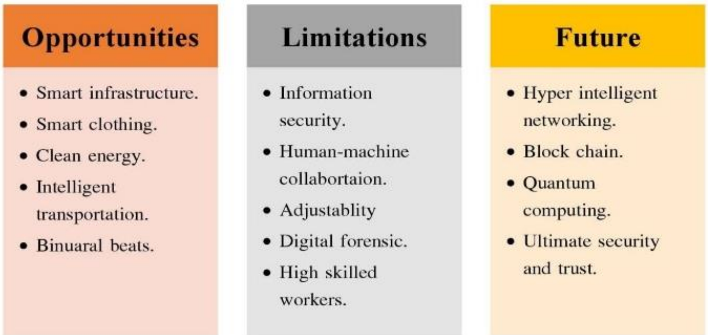


Fig. 3 Opportunities, Limitations and Future of Industry 5.0

However, Industry 5.0 also faces limitations. Information security becomes crucial as technology integration increases, necessitating stronger measures against cyber threats. Human-machine collaboration requires new approaches and training programs to optimize productivity and cooperation. Adaptability becomes essential due to rapid changes in the industry, requiring businesses to embrace new technologies and adapt their models to shifting market conditions. The digital nature of Industry 5.0 necessitates digital forensic services to investigate cybercrime and data breaches. Additionally, the demand for high-skilled workers rises to handle the complexity of Industry 5.0, necessitating robust training and development programs. Looking ahead, the future of Industry 5.0 holds promising developments. Hyper-intelligent networking enables real-time data processing for applications like traffic control, self-driving cars, and virtual reality. Blockchain, a distributed ledger technology, has the potential to revolutionize industries such as finance and supply chain management. Quantum computing, utilizing quantum mechanics, can solve previously unsolvable problems, impacting fields like drug discovery and artificial intelligence. Striving for ultimate security, Industry 5.0 seeks unbreakable security measures to safeguard data and systems.

In summary, Industry 5.0 offers significant opportunities in smart infrastructure, clean energy, intelligent transport, and binaural beats. However, limitations in information security, human-machine collaboration, adaptability, digital forensics, and skilled workforce require attention. The future of Industry 5.0 looks promising with advancements in hyper-intelligent networking, blockchain, quantum computing, and ultimate security.

The implementation of Industry 5.0 and the development of several industries, including medicine, hospital, the biosciences, marine, academia, tourism, and entertainment, were the main topics of another batch of studies in the framework of Industry 5.0 (Fig. 4). The Green, Resilient and Inclusive Development (GRID) model, put out by the WEF and the WB, is consistent with the industry 5.0 pillars of conservation, technical advancement, and social equality [18, 20]. The GRID model offers a great lens through which to view the complexities of implementing Industry 5.0 [21, 22].

Fig. 4 Applications of Industry 5.0

Although the technology "Industry 5.0" was first used roughly a few years ago, important publications on the topic have just been released. Despite important fields like hotels, training, medical services and pharmaceuticals, power generation, and human-centric viewpoints being examined in relation to the implementation and influence of Industry 5.0 from a scientific viewpoint, to our understanding none of the researches was concentrated on barriers that industries can inevitably experience while incorporating Industry 5.0 [23]. Our research is new because, whereas the majority of studies have been conducted from the viewpoint of industrialized nations, none have addressed the views of barriers in industry 5.0 and their mitigation. Sachsenmeier [11] on bionics study work is particularly related to industry 5.0 and synthetic biology. The outcome of this study shows the necessities of synthetic biology and bionics in the industrial era. Özdemir and Hekim [24] made their study on policies that are relevant to industry 5.0 and multiple technologies. The outcome of this study reveals that an industry is a meshwork of complex interconnected networks and various devices. It is important to ensure that the devices that are used in industries must be safe and sustainable. Nahavandi [25] introduced the solutions for human centricity for industry 5.0 purposes. These solutions are for the challenges that are faced by manufacturing firms. Demir et al. [26] gave the idea of co-working robots with humans. They compared the goals and visions of industry 4.0 and industry 5.0 and crucial barriers are also discussed in this study that considers co-working of humans and robots. Abdel Basset et al. [19] conducted a study on soft computing and the Next generation of IoT or the Internet of things. When it comes to the development of industry 5.0, Soft computing and IoT are very important components. Fukuda [27] worked on ecosystem models based on STI or Science, Technology, and Innovation. These models review the STI policies and statistical analysis which compare the progress of the ecosystem of Japan with Germany and the US. Sharma et al. [28] worked on the industrial impact on smart cities. Their work makes predictions about how smart cities are impacted by industries 5.0 and highlights the modifications that are required for personalization and efficient co-working of humans and robots. Ciasullo et al. [16] worked on healthcare 4.0 introduction for the awareness of society 5.0. Their study shows the importance of healthcare 4.0 and its contribution towards proper care and appropriate treatment for patients suffering from bedsores. Bartoloni et al. [29] investigated the application of the design of the Quintuple Helix. This conceptual model was based on designs that are related to the application method of the Quintuple Helix. Pillai et al. [3] conducted a study focused on Covid 19 and redefining operations of hospitality 5.0. This study reflects the principles that are designed in the related of hotel industry 5.0. Thakur and Sehgal [30] made an architectural proposal that was related to SCPS or Smart Cyber-Physical System. This architectural structure for SCPS was proposed for industry 5.0 and used in multiple industries like paper, petroleum, cement, fertilizer, and automobiles. Carayannis et al. [31] worked on the energy produced by nuclear fusion and its utilization in future industry 5.0. This work highlights the importance of energy produced in nuclear fusion and its industrial utilization. Maddikunta et al. [32] conducted a survey related to industry 5.0 and their industrial application. This work shows different features of technologies and methods of their application along with their challenges. Xu et al. [33] conducted a study to clarify different perceptions and for a better understanding of industry 4.0 and industry 5.0. Their work elaborates on the differences in technologies, core values, concepts, and challenges between industry 4.0 and industry 5.0. Madsen and Berg [12] made an analysis exploring new literature related to industry 5.0. Their literature survey covers the period between 2015 and 2021. It indicates that industry 5.0 is a novel field. Most of the articles were written after 2019 and only 5 belonged to the top used articles. Broo et al. [15] worked on the education of engineering for industry 5.0. This work provides a brief history of the learning of engineering and the importance of critical challenges, skills, and plans that are learned and practiced.

3. Potential Barriers

3.1. Security and Privacy

Industry 5.0 is anticipated to introduce a multitude of network topologies, operations, equipment, technologies, systems, and terminals that will help to close the separation between the physical and digital worlds. Although the above components constitute a close network, businesses must guarantee that there isn't a security violation without sacrificing service and operational standards [32]. To guarantee the achievement of Industry 5.0, businesses must solve security issues relating to verification, accuracy, password protection, and accountability. As Industry 5.0 develops, it is also anticipated that data will be openly transmitted over the internet between numerous linked devices, networks, partners, robots, people, and platforms, raising issues about privacy and data protection. Data privacy is a major problem for both international companies and governments since data is extremely valuable and, if misused, might have a number of ramifications for the focus business and its associates [34].

A new danger pathway will be created by Industry 5.0's usage of AI and enabling technologies. For security reasons, trustworthy implementation is crucial for AI/ML operations. For Industry 5.0 implementation to function properly, it is especially important to safeguard the accuracy of the data set in use for ML model training and the AL method [35]. For example, Industry 5.0 renters must safely exchange scientific data to train AI models or modify models incrementally, as in supervised learning. Deploying proactive security procedures [36] and mitigating zero-day threats [37] are only a couple of the new security protocols that will result from Industry 5.0's increased reliance on ICT systems. Additionally, Industry 5.0 may function in the quantum computing age because of the growth of quantum computing. A quantum computer will significantly simplify protecting old security measures [38]. In such circumstances, Industry 5.0 platforms must use post-quantum encryption or cryptography that is quantum resilient to guarantee the necessary degree of security [39]. Privacy is a crucial need for Industry 5.0 services since the whole environment relies on valuable scientific property, cost - effective production inputs, and access control [40]. To link robots and people, engineers and other partners, and to transmit surveillance and management data, data is transmitted via the Internet in Industry 5.0. To maintain the confidence of the cloud-based network, such information cannot be accessible to hostile Web users [34]. To prevent a detrimental society effect, particular sociological and moral considerations must be followed while adopting AI. Human workers frequently worry that AI will make their occupations obsolete, while Industry 5.0 will provide more job prospects. To enable continuous co-production between humans and robots, the moral concerns concerning AI and its effects on people should be resolved [41]. Robots must include social decisions, ethical principles, social interactions, and cultural norms [42]. The industrial revolution's authorities must take into consideration the moral dilemmas raised by cooperation between humans and machines. Human data protection laws, or the idea that persons have ownership over their data, are one of the privacy concerns. They are entitled to compensation for any data breaches that affect their personal or critical data. In order to protect data privacy, user data must be protected while being used for analytical reasoning and preventative management.

3.2. Scalability

Industry 5.0 is now in its infancy, but as time goes on, it will include a network of thousands of linked equipment, devices, and people that will collectively improve efficiency, performance, and security [43]. To expand up and link to and create such a broad network, businesses must be sensitive to the need and growing activity. Therefore, adaptability is the capacity of any technology to adapt to an overall rise in its activity [32]. The systems operating under Industry 5.0 must be capable of scaling up to increase production thanks to the many linked devices and software. This is crucial in co-working spaces where people and robots are linked via the web to a variety of gadgets and software. It is a serious reason for worry [28]. Using 3d printing e.g., among the most exciting Industry 5.0 systems, businesses would be required to take the necessary steps to build barrier ability to be able to expand to meet any growth in market trend, despite the case of customized and unique goods, without lengthening timeframes [44]. Once the system's activity varies continuously, scalability may be defined in terms of the system's resilience, adaptability, and reactivity. Scalability in Industry 5.0 refers to a system's effectiveness in various working situations, regardless of whether there are more or less hyper-connected systems present in the ecosystem. Industry 5.0 is designed to link and converse with a variety of systems from other industries as well as a variety of people. Scalability is a feature of Industry 5.0, which is an improvement of Industry 4.0, however creating a companionship between humans and machines or robots by combining their task poses a more serious difficulty [45]. Employing service level signals that have been verified in accordance with the service level goals outlined in service level contracts, the scalability may be followed up. This is a crucial issue since non-determinism is growing in the rise of data gathering, equipment, manufacturing, and human activity. Technology providers in the industry 5.0 ecosystem should be capable of providing services at any capacity, adaptable enough to extend and grow, and give a low-latency solution with no data analysis latencies to assure scalability. The many inquiries received from the adaptable cloud and dynamic edge servers should be processed by AI-based robots with no unforeseen latency.

Scaling Additive Manufacturing (AM): Throughout manufacturing, hundreds of printers may be operating in the same capacity and might be meant for the identical component demand. In these situations, AM must grow itself according to the automation infrastructure and increasing expectations. With no traditional limitations, AM enables on-demand production to create more personalized items with shorter lead times. They are challenges peculiar to AM scaling [44]. The method selection for utilizing AM findings and expanding them for manufacturing usage is one of the issues. Finding the obstacles to AM expanding into manufacturing and developing mitigation strategies is the second problem. The third problem is AM's inability to adapt to emerging market dynamics. Demand-based counter productiveness can encourage AM scaling. Using 4D or 5D printing technology along with effective software for designs might improve the challenges with AM scaling in manufacturing. For the industry-wide implementation of AM, AM scaling criteria must also be created and improved. As the amount of data stored on the cloud platform grows, analyzing that data may take a surprisingly long time, delaying responses. Micro data centers will now allow the integration of EC with AI at network edge devices. As was previously said, EC will minimize latencies to ensure low latency replies, and the edge server will become a smart edge when AI makes data forecasts there.

3.3. Legal and Regulatory

Although most countries have basic rules and guidelines in place relating to the last technological growth, legislation governing advancements in Industry 5.0 must be implemented. In addition to human-robot teaming, 6G, digital twins, 3-d printing, drone technology, networked, smart gadgets, and system software, Industry 5.0 is anticipated to provide fresh, better methods of working [32]. It is necessary to create new laws and regulations that regulate the general ecosystem layout, as well as rules for human- robot cooperation and discriminating between different sorts of robots and machines, such as robots and drones, in order to control each of them [26]. In addition, it's important to develop clear regulations for technological advancement and ecosystems that include mobility and adaptability [33]. Many rules relevant to both the human and robot should be developed as Industry 5.0 seeks to bring again the human labor to collaborate with robotic systems and smart technology [46]. Lacking appropriate rules and laws, several problems might develop in this co-production setting [26]. Robots should be distinguished from many other robots, such as drones, by laws that are implemented.

3.4. Ethical Concerns

Industry 5.0-related ethical problems may be divided into two categories. The first type of ethical quandary of human-robot collaboration may arise, such as putting moral standards into machines, aligning human-robot working morals, and people management and devices collectively in the company to assess their efficiency and conduct [25, 26]. Utilizing AI and machine learning (ML), the second type of material difficulties might occur. These issues also included deciding whether to use robots in routine, routine tasks instead of people, lowering worker salaries in favor of more affordable machine substitutes, and protecting personal information [42, 47].

3.5. Upskilling, Reskilling and Talent Retention

The 10 abilities that production will need in the future have been recognized by the World Manufacturing Forum [48]. Media literacy, AI and big data, innovative problem-solving, an innovative approach, physical and behavioral worker protection, a comprehensive and variability attitude, a confidentiality and security-oriented attitude, the ability to manage growing workload, useful connectivity skills, and an openness to ongoing change are a few of these. Only four of the aforementioned abilities are computerized, as can be seen from the list above; the others are more focused on originality, mentality, and innovative thinking [43].

Additionally, analysts believe that when Industry 5.0 emerges, robots may begin to do routine daily tasks. Humans may simultaneously need several and specialized expertise, such as those for managing unique circumstances, innovation, and architecture [48]. This might create a skills deficit and provide possibilities for novel employment that might not otherwise exist. Considering that Industry 5.0 remains in its very early stages, organizations, community, and the government may not be prepared to provide the necessary instructors and training programs [49].

To tackle any technical, societal, and administrative challenges, standards and legal rules must be implemented since a competent employee in Industry 5.0 is required to offer a high-value job in manufacturing. Challenges with organizational, personnel, corporate culture, and organizational technology are only a few of the issues involved in providing a trained workforce [14]. Insufficient instructors and cost limitations make it difficult for people who work alongside robots to receive the necessary teaching, which is the main skill area difficulty. The need for competent workers and new technologies will increase by the period Industry 5.0 is completely implemented, necessitating proper training both for the learners and the future instructors. This may encourage public-private collaborations [50]. Reforming the regulatory framework will also be required. The skilled employee can also support operational effectiveness. Many sectors would adopt the latest emerging innovation to keep up with digital competency, but administration could not be aware of it. The knowledgeable staff and the environment could take advantage of the company's incompetence.

3.6. Acceptance and Adaptability

Modern working methods will be introduced by industry 5.0, such as the fusion of cyber and real workspaces, human-robot collaboration, the employment of modern technology, and the potential automation of human labor to save time and money [33]. Because they are afraid of being substituted more by effective machines and robots, the aforementioned might make people resistant, which would prevent them from accepting social variety [26, 49].

Humans will once again work alongside robots on the production floor thanks to Industry 5.0. Although it appears to be a productive technique to create customized goods, several concerns about the interaction between humans and robots should be considered. Additionally, when people and robots exchange labor, human job loss anxiety will be reduced. The robot will do the routine tasks, freeing up the human to focus entirely on ideas and creativity. It will be preferable for robots to support humans than the other way around, which might lead to organizational instability and disrupt the company's long-standing job competitiveness environment. This could lead to several difficulties, including shifting the responsibility of human resources, robotics in IT departments, ethical principles with robots, training people to start competing with robots, legal requirements, mental issues to force people to implement a new approach to working, and job mechanisms assessment for both humans and robots [49]. Additionally, robot workers are competent and may have higher expectations than those of a regular work environment.

3.7. Cost and Funding

Industry 5.0 would feature excessive technological exploitation, human-robot collaborative work, and mass customization via networked gadgets [27]. Industry 5.0 would feature excessive technological exploitation, human-robot collaborative work, and mass customization via networked gadgets. Both the main enterprise and the local government would need to make significant expenditures on them. Financing becomes a significant barrier since organizations and emerging economies with other objectives may only consider short-term returns and link these investments with high expenses [33].

3.8. Regional Disparity

An absence of sufficient absorption of Industry 5.0 concepts throughout all sectors may result from widening demographic and technical divides between urban and rural areas [27]. Consequently, it might pose a serious threat to the effective implementation of Industry 5.0.

4. Risk Mitigation

Understanding the obstacles to Industry 5.0 acceptance is made easier by the understanding of these hurdles. However, merely identifying problems does not guarantee that Industry 5.0 will be successfully adopted in the actual world. In order to successfully implement Industry 5.0, we need an appropriate mitigation approach. To achieve this, we are working to create a mitigation plan that focuses on the GRID architecture [48]. The World Economic Forum and the World Bank have combined their efforts to create this structure [18, 20]. The three main pillars of the GRID strategy are sustainability, resilience, and inclusivity. Economic equality, universal development, and positive future are the shared goals of each pillar of the GRID structure. Other theoretical perspectives, such as resource-based view and dynamic capabilities, recommend that businesses build the capacity to address functional difficulties and achieve a strategic advantage.

Technology implementation may increase a company's capabilities, but RBV [51] and DCV are mostly mute about how to get through obstacles that a company can have while deploying new technology [2] such as Industry 5.0. Contrarily, the GRID structure distinctly proposes three pillars that can assist businesses in overcoming obstacles. Additionally, we introduced the GRID structure to professionals, who concurred that it is an appropriate technique for creating a model for the quicker implementation of new technologies, including Industry 5.0 [48]. It's noteworthy to note that Industry 5.0 technology necessitates tight machine-human-interface interaction. But the majority of the frameworks emphasize either men or machinery more. GRID systems offer a broad perspective and take both machines and men and women into account.

Within the GRID structure, we offer our mitigation plans for the eight noted barriers [48]. These mitigating measures would speed up the adoption of Industry 5.0 by industrial companies. Below, we will go into depth about each of these pillars, classifying the eight obstacles that have been found as well as the corresponding suggested mitigation measures.

4.1. The Green Pillar

The green pillar emphasizes development for the future and calls for the transformation of vital industries and activities, such as production, communication, and electricity, in order to build a more environmentally friendly and prosperous future [48]. The most noticeable barrier that connects to all other obstacles is barrier B7 (price and finance). Pricing and finance should be the backbone of every technology and growth endeavor, so this is obvious. In addition to 6G, digital twins, 3-d printing, drone technology, networked smart gadgets, and various systems, Industry 5.0 is anticipated to provide fresh, better methods of working [32]. Modern, appropriate methods must be used to control each of them [26]. Speed and adaptability must be taken into account when defining clear regulations for technology and sustainable environment development [33]. In the reason important groups, the barrier B3 (legislative / regulatory) also has a high rating, showing that it has a strong impact on other obstacles. According to rumors, Industry 5.0 will entail excessive technological exploitation, human-robot collaboration, and mass customization via linked gadgets. Both the main enterprise and the local government would need to make significant expenditures on them. Investment may be a key barrier since emerging countries with competing interests and organizations that simply priorities short-term advantages may link these investments with large expenses [27, 33].

The authorities and legislative organizations would be required to offer long-term plans and rewards, like tax refunds and vacations for businesses that use environmental and human-centric activities while still maintaining revenue, to overcome the aforementioned two key impediments [48]. The governmental and legislative organizations must discover new methods of functioning that Industry 5.0 intends to offer in order to address the obstacle connected with legal and governmental difficulties. After that, they might review the current laws in order to create new rules that would cover all areas of Industry 5.0, including limitations on cutting-edge technology and human-robot collaboration [48].

4.2. The Resilient Pillar

The Resilient pillar focuses on risk mitigation to prevent any risks, whether they be natural or man-made, as well as social and eco-technological disasters. In order to safeguard market segments, equipment, and the general public from crises, this would urge major nations and international organizations to spend in risk mitigation and prevention strategies [48]. This pillar is responsible for barrier B2, which is the second most noticeable barrier and is joined by barrier B1, which is extremely important. Systems operating underneath Industry 5.0 must be able to expand to meet demand thanks to the many linked devices and programs. This is crucial in office spaces where people and robots are linked via the internet to a network of gadgets and services. It is viewed as a serious source of worry [28,32]. To guarantee the performance of Industry 5.0, businesses must solve security issues with relation to verification, reliability, password protection, and accountability [52].

Additionally, academics anticipate that the emergence of Industry 5.0 will result in data being openly transmitted throughout the internet between numerous interconnected devices, networks, partners, robots, people, and platforms, raising worries about data privacy and security [48]. The authorities would be required to step in and impose extra identification and security measures, as well as an independent audit for each action taken across the connection of equipment and systems. Businesses would have to shift their attention away from strategic short-term advantages in expansion and towards a longer-term strategy [48]. Large businesses may gain from government assistance in the form of tax breaks and substantial interest-free financing.

4.3. The Inclusive Pillar

The comprehensive pillar emphasizes social interaction and human resources, and it works to guarantee that everyone may thrive in a welcoming atmosphere. The reduction of inequities that could exist in resources and results is the pillar's end goal. The greatest obstacle in the temporal group is barrier B6 (acknowledgement and adaptation). A general result of making sure that every person's wants and expectations are taken into account would be less opposition, which would facilitate smoother and faster adoption of novel operating methods through Industry 5.0 in terms of technical and social transformation. Due to work morals when humans and robots collaborate together, barrier B4 (moral problems) might appear [25] and concerns about robots and technology taking the place of the present employees [42]. Additionally, barrier B5, which entails skills training, retraining programs, and talent management, will be addressed concurrently. This means that worries about a skills gap, moral conundrums, and fears related to human-robot collaboration might be eliminated with spending in teaching, learning, and growth of the workers in modern technology and methods of functioning [48].

Another significant obstacle, B8 (Area inequality), which is brought on by the widening demographic and technical divide between urban and rural regions, particularly in emerging and impoverished countries, is a source of considerable worry [27]. In collaboration with the businesses under discussion, local authorities and organizations should develop area regeneration measures such as refunds, the supply of assets, and technology. The goals of Industry 5.0 will be achieved if businesses are encouraged to establish centers and production operations in rural and non-urban locations. With the three aforementioned pillars in place, it is anticipated that all countries and worldwide enterprises in their eagerness to adopt and utilize the benefits of Industry 5.0 shall harvest the similar goals of development, conservation, technology progress, and social wealth [48]. In order to achieve this, this study looks at the ranking of and connections between the barriers to Industry 5.0 adoption from the managers' perspective who decide which technologies to implement within the company. To the best of the authors' knowledge, this study is the first to explore adoption hurdles for Industry 5.0 by delving into their causes. Ranking the adoption hurdles of Industry 5.0 and understanding how they relate to one another will help determine how the technology will be most successfully adopted and applied in the manufacturing sector, particularly in emerging nations, in the future.

4.4. TODIM

Fuzzy sets (FS) are a way to describe and handle data that are not rigid but slightly hazy, with membership values ranging from 0 to 1, according to Zadeh [53]. Also, he put out an original fuzzy set theory that is a useful tool for solving practical issues. The Neutrosophic set (NS), according to Smarandache [54], deals with truth, falsehood, and indeterminate membership functions, all of which are unrelated to one another. It can be challenging to discuss a decision-making conundrum with NS. As the three degrees of truth, falsehood, and indeterminacy cannot be stated as precise numbers, computing them in real-world contexts is challenging [55]. Recently, some researchers developed an environment using interval values to address this problem, where the membership value is established using an interval number rather than a precise integer. Although intuitionistic fuzzy sets and interval-valued intuitionistic fuzzy sets cannot manage indeterminacy, many scholars have widely recognized Interval Neutrosophic Sets (INS) and proposed a similarity measure between INSs based on Hamming and Euclidean distances. In fields like decision-making, information fusion, image processing, and medical diagnostics, the application of NS and INS theories has yielded a number of promising findings [56]. The fuzzy set is incapable of handling all forms of uncertainty, including inconsistent and indeterminate data [57]. There is uncertainty since several experts are unsure of the claim. The FS and IFS, which deal with membership, non-membership, and hesitant functions, do not address these issues. Using NS, we can find a solution to this issue. Using membership values between [0, 1], aggregation operations in an intuitionistic fuzzy environment can be expanded to NS. Consequently, we must focus on aggregation operators on NS in order to aggregate Neutrosophic information in decision-making circumstances. The idea that the three membership functions in NS are independent will be very beneficial in the field of information fusion, according to [58]. An original technique for decision support is required in multi-criteria analysis to address uncertainty and human viewpoints. In a multi-criteria decision-making process, the decision matrix is made up of criteria and alternatives. We employ fuzzy numbers in real-world circumstances since this matrix is subject to uncertainty. This is a membership grade interval extension. Each value in the interval relates to a real number and can be used with an uncertainty declaration. This method was also applied to MCDM by [58]. For determining an exact number as the grade of membership of the decision makers, there are many decision-making techniques, but there are few for calculating an interval-based fuzzy number. Researchers Gomes et al. [59, 60] are engaged in a project. The TODIM methodology is an MCDM method based on prospect theory. The decision maker's choice is effectively acted out in risk scenarios, and the global measurement value is established utilizing PT TODIM. The global multi-attribute value function will combine all loss and gain measures. Since each alternative's global value is proportional to its dominance over all other alternatives, TODIM is comparable to outranking techniques. This approach, which is based on a single parameter, tests particular gains and losses functions. A non-compensatory strategy, as the name implies, does not take into account compromises. To get rid of differences, this technique uses paired comparisons. A technique for iterative MCDM is TODIM. This approach chooses and reorders the objects in accordance with the advice of the expert. The complete information regarding the attributes will be made available here. Insufficient information about attributes is frequently provided by experts, making it challenging to address decision-making problems. With incomplete attribute matrices, TODIM is especially useful since its judgements are more unbiased and widely accepted. MCDM concerns are often divided into two categories: benefit criteria and cost criteria. Benefit criterion will typically take precedence over usage convenience. Adali et al. [61] claim that measuring the degree to which each alternative dominates the other alternative is the key tenet of the TODIM technique. Hence, both qualitative and quantitative criteria can be used using this approach. The applicability of the TODIM technique for varied fuzzy circumstances was explained by Qin et al [62]. One of the MCDM strategies Gomes and Lima offered is the TODIM approach, which Krohling and Souza [63, 64] found employs Fuzzy TODIM and the extended case and is based on prospect theory. Gomes et al. [65, 66] used TODIM and Choquet integrals in order to streamline calculations and support interval data. The best option was chosen using a combination of TODIM and FSE by Passos et al. in 2014 [67]. Wei et al. [68] introduced the hesitant fuzzy linguistic TODIM technique. To understand heterogeneous data, Lourenzutti and Krohling [69-71] improved a novel strategy based on the TODIM method. Li et al. [72] suggested intuitionistic fuzzy TODIM for the distributor problem. Fuzziness was used by Tosun and Akyüz [73] to enhance the shortcomings of a relatively new decision procedure termed TODIM. Ren et al. [74] and Zhang et al. [75] introduced the enhanced version of the TODIM method using the Pythagorean fuzzy sets and Neutrosophic numbers. This method was repurposed as a decision-making reinforcement method by Lin et al. [76]. The interval type-2 fuzzy sets TODIM technique was developed by Sang and Liu [77] and utilized to address a challenge in the supplier sector. Pramanik et al. [78] introduced the NC-TODIM method to address an investing issue. Qin et al. [62] extended the traditional TODIM technique for an MCDM problem. Sun et al. [79] used extended TODIM and ELECTRE III techniques for the physician selection challenge.

He et al. [80] demonstrated aggregation capabilities for INS utilizing the INWA operator and satisfied decision makers' needs using HMF-TODIM. The 2TLNNs TODIM methodology, which expands the TODIM method to the 2-tuple linguistic Neutrosophic fuzzy environment, is suggested by Wang et al. [9] to provide the criteria values in issues involving multiple attribute group decision-making (MAGDM) utilizing the enhanced technique of 2-tuple linguistic Neutrosophic numbers (2TLNNs). A furniture manufacturing company will be required to resolve a real-life case study. In 2019, Deng and Gao Heo [81] expanded the 2TLPFs TODIM method. Thus, the Pythagorean fuzzy 2-tuple linguistic environment is added to the original TODIM technique. Davoudabadi et al. [82] presented a novel paradigm in 2020 for dealing with multi-attribute group decision-making issues in fuzzy environments. By merging Schweizer-Sklar t-conorm and t-norm (SSTT) aggregation operators, power average (PA) operators, and TODIM processes, Zindani et al. [83] provide a novel integrated group decision-making framework for decision making in intuitionistic fuzzy settings. While there is no enough study on INS, we used the TODIM approach to solve an investing dilemma based on the aforementioned literature.

Fuzzy tri-angular aggregation operators are a brand-new class of fuzzy aggregation operators that Ulrich and Henri [84] introduced. To analyses ambiguous or erroneous data, another strategy—fuzzy numbers—must be utilized. To do this, we focus on circumstances where it is impossible to quantitatively analyze the available data. Liao et al. [85] explained multiple attributes group decision making using the cumulative prospect theory in a probabilistic hesitant fuzzy setting. Leoneti et al. [86] explained Based on the exponential model of prospect theory, a novel application of the TODIM method. Sun et al., [87] explained Using the Z-Wasserstein distance, an expanded Exp-TODIM approach for multiple attribute decision making.

4.5. DEMATEL

Previous studies in this field indicate that MCDM (Multi-Criteria Decision Making) Techniques are most frequently used to overcome the aforementioned challenges. AHP (Analytic Hierarchy Process), TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), and ANP (Analytic Network Process), to name a few, are just a few of the approaches that fall under the umbrella of the aforementioned MCDM technique. However, the DEMATEL method manages to take into account how various criteria interact and, hence, it is well adapted to tackle real-world issues [88,89]. Considering in light of the aforementioned, we approach our research challenge using the DEMATEL (Decision Making Trial and Evaluation Laboratory) strategy. The DEMATEL methodology was initially created by the Battle Memorial Institute of Geneva in the early 1970s [90], and since then it has been widely applied to solve practical problems involving the interrelationship between various factors or criteria [91]. Sheng et al. [92] explained the systematic review of DEMATEL. Romel et al. [93] explained the analysis of the barrier in waste management. Wenping et al. [94] detailed analysis of the variables affecting the supply chain for emergency logistics.

4.6. Single Valued Neutrosophic

The phrase "single-valued neutrosophic set" (SVNS) refers to a particular type of neutrosophic set that is distinguished by having membership functions for truth, indeterminacy, and falsehood that all fall inside the range [0, 1]. Riaz et al. [95] explained operators for single-valued neutrosophic reasonable aggregation with multi-criteria judgement. Granados [96] discussed the application of quadripartitioned single-valued neutrosophic properties to energy price influencing factors. Liu and Yang [97] explained college and university physical education teaching quality evaluation using the DAS method for single-valued neutrosophic number multi attribute group decision-making. D. Nagarajan and Kavikumar [98] explained neutrosophic hidden Markov model with single-value and interval values. Wang et al. [99] explained that a cost-sensitive, multi-scale, single-valued neutrosophic decision-theoretic rough set is used to determine the best scale. Nagarajan et al. [100] explained an innovative method for multi-attribute group decision-making based on the neutrosophic Bonferroni mean operator of trapezoidal and triangular neutrosophic interval environments.

5. PRELIMINARY

5.1. Neutrosophic Sets

In this section, we define some definitions and arithmetic operations for a Neutrosophic set used in forthcoming sections.

Definition 1. [54] Let U be the universal set, then Neutrosophic set is defined as $A = \{(T_A(x), I_A(x), F_A(x)), x \in U\}$ where $T_A(x), I_A(x), F_A(x) \in]0^-, 1^+[$ and $0^- \leq T_A(x) + I_A(x) + F_A(x) \leq 3^+$.

Definition 2. [101] Let U be the universal set, then SVNS is defined as $\dot{A} = \{(T_{\dot{A}}(x), I_{\dot{A}}(x), F_{\dot{A}}(x)), x \in U\}$ where $T_{\dot{A}}(x), I_{\dot{A}}(x), F_{\dot{A}}(x) \in [0,1]$ and $0 \leq T_{\dot{A}}(x) + I_{\dot{A}}(x) + F_{\dot{A}}(x) \leq 3$.

Definition 3. [102] The proposed score function for the Neutrosophic triangular set is given by, $\dot{S}^*\left(T_A(x), I_A(x), F_A(x)\right) = \frac{1}{2}\left(1 + T_A(x) - 2 * I_A(x) + F_A(x)\right)$.

5.2 Single Valued Neutrosophic Sets (SVNS)

Let X be the universal set and for $\forall x \in X$, SVNS [103] is defined as $N = \{\langle x, T_N(x), I_N(x), F_N(x)\rangle, x \in X\}$ where $T_N(x)$, $I_N(x)$, $F_N(x) \rightarrow [0^-, 1^+]$ are the truth, indeterminacy and falsity-membership function and satisfy the criterion $0^- \leq T_N(x) + I_N(x) + F_N(x) \leq 3^+$. The membership function of the embedded sets of an Neutrosophic sets satisfy $\underline{T}_N(x) \leq T_N(x) \leq \overline{T}_N(x)$, $\underline{I}_N(x) \leq I_N(x) \leq \overline{I}_N(x)$ and $\underline{F}_N(x) \leq F_N(x) \leq \overline{F}_N(x)$.

Definition 4. (Single Valued Neutrosophic Weighted Operator) [104] Let $W_A = \sum_{i=1}^{n} \omega_i A_i = 1 - \prod_{i=1}^{n}(1-T)^{\omega_i}, \prod_{i=1}^{n} I^{w_i},, \prod_{i=1}^{n} F^{w_i}$, where ω_i is the weight of A_i and $\omega_i \in [0,1], \sum_{i=1}^{n} \omega_i = 1$.

Definition 5. (Single Valued Neutrosophic Geometric Operator) [104] Let $W_G = \sum_{i=1}^{n} \omega_i G_i = \prod_{i=1}^{n}(1-T)^{\omega_i}, 1 - (1 - \prod_{i=1}^{n} I^{w_i}), 1 - (1 - \prod_{i=1}^{n} F^{w_i})$, where ω_i is the weight of A_i and $\omega_i \in [0,1], \sum_{i=1}^{n} \omega_i = 1$.

Definition 6. (Score Function) [104] Let $A = (T_A, I_A, F_A)$ be a single valued neutrosophic set, a score function $S(A)$ is defined as $S(A) = \frac{(2+T_A-I_A-F_A)}{3}$, $S(A) \in [0,1]$. The score function for ranking in single value neutrosophic set is defined as $R = \frac{1+a-2b-c}{2}, R \in [0,1]$. The properties of R is $R = 0$ if and only if $a = 2b + c - 1, R = 1$ if and only if $a = 2b + c + 1, R = -1$ if and only if $a = 2b + c - 3$.

Definition 7. [55] Let A and B be two single-valued neutrosophic sets, the basic operations of single valued neutrosophic sets are:

$$A \oplus B = (T_A + T_B - T_AT_B, I_A I_B, F_AF_B). \tag{1}$$

$$A \otimes B = (T_AT_B, I_A + I_B - I_A I_B, F_A + F_B - F_AF_B). \tag{2}$$

$$\lambda A = 1 - (1 - T_A)^{\lambda}, (I_A)^{\lambda}, (F_A)^{\lambda}, \lambda > 0. \tag{3}$$

$$(A)^{\lambda} = (T_A)^{\lambda}, (I_A)^{\lambda}, 1 - (1 - F_A)^{\lambda}, \lambda > 0. \tag{4}$$

6. Identification Barriers

We have assumed that an identification barrier is the best alternative for their mitigation in industry 5.0 [105]. The decision-making board based on four decision-makers who assess the five choices. The five choices are as follows:

(A1) Regional disparity, Scalability and upskilling reskilling and talent retention (a_1): Growing socioeconomic and technological disparities between urban and rural areas could pose a serious threat to the successful implementation of Industry 5.0. Any system's resilience to an exponential change in its workload depends on its ability to scale. Systems operating under Industry 5.0 should be able to scale up to meet demand thanks to the many interconnected devices and applications. This is crucial in co-working settings where humans and robots may be connected over the internet to a landscape of gadgets and applications. Humans may need various specialized skill sets, such as handling extraordinary scenarios, inventiveness, and designing, whilst robots may take on monotonous day-to-day tasks. This might create newer professions that don't already exist, creating a skills shortage. Given that Industry 5.0 is still in its infancy, organizations, society, and the government may not yet be prepared to provide the necessary trainers and training programs.

(A2) Acceptance and adaptability (a_2): One major obstacle is the resistance to using robots and other technology at work. Concern that machines might supplant people in their current jobs could prevent people from being adaptable.

(A3) Legal and regulatory (a_3): While most countries have general laws and regulations governing the previous industrial revolution, there still has to be enforcement of laws regarding specific advancements in Industry 5.0. It is necessary to develop laws and rules that address the broader ecosystem's orientation, directions for human-robot cooperation, and ways to distinguish between different types of robots and other technologies like drones and robots.

(A4) Cost and funding (a_4): According to rumors, Industry 5.0 will entail excessive technological exploitation, human-robot collaboration, and mass customization through connected gadgets. Both the main enterprise and the local government would need to invest large sums in these. These costs and funding may be seen as a major barrier by developing countries that may have other priorities as well as organizations that may focus on short-term gains.

(A5) Ethical concerns (a_5): Co-working between humans and robots may raise ethical concerns, such as the application of morality to technology. The use of AI and machine learning (ML) may potentially raise ethical concerns, especially if robots begin to take the place of people in routine tasks.

6.1 Methods

The following steps to find the rank of the attributes using SVNWA and SVNGA

Step 1: Normalizing the data

Step 2: Compute the dominance degree $\delta(A_i, A_j) = \sum_{k=1}^{n} \gamma_k(A_i, A_j), i, j = 1,2,3, \ldots . m$

Step 3: Compute the overall value

$$\gamma_k(A_i) = \frac{\sum_{j=1}^{m} \gamma_k(A_i, A_j) - \min\left(\sum_{j=1}^{m} \gamma_k(A_i, A_j)\right)}{max \sum_{j=1}^{m} \gamma_k(A_i, A_j) - \min\left(\sum_{j=1}^{m} \gamma_k(A_i, A_j)\right)}$$

Step 4: Ranking all alternatives

The primary steps in our research technique are as follows. Initially, as stated in sections, we carried out a thorough literature analysis to find any potential obstacles to Industry 5.0's successful implementation. The second stage was to present the identified barriers to 14 industry experts so they could conduct a survey to find out how one barrier affected the others. In the third phase, we used the aforementioned data set to rank these obstacles and divide them into cause-and-effect groups using a well-known MCDM (Multi-Criteria Decision Making) approach called TODIM method and compare with DEMATEL (Decision making Trial and evaluation laboratory). Finally, we presented our findings to three business and two academic experts, along with a comprehensive mitigation strategy to address the key obstacles to implementing Industry 5.0. Given that it takes into account how several criteria interact, it is well adapted to tackle real-world issues. Taking into account the aforementioned, we employ the Neutrosophic TODIM technique to solve our study topic.

7. NUMERICAL PROBLEM

A straightforward linguistic scale was employed (N = No Influence, VL = Very Low Influence, L = Low Influence, M = Medium Influence, H = High, and VH = Very High Impact). If the possible company A_i (i=1,2,3,4) are determine by the Neutrosophic matrix:

$$\widetilde{R} = \begin{bmatrix} (0.3,0.6,0.1) & (0.4,0.2,0.1) & (0.1,0.6,0.1) & (0.5,0.7,0.2) \\ (0.6,0.2,0.1) & (0.8,0.2,0.2) & (0.6,0.2,0.3) & (0.8,0.2,0.1) \\ (0.5,0.6,0.1) & (0.5,0.7,0.1) & (0.5,0.3,0.1) & (0.6,0.3,0.1) \\ (0.7,0.1,0.3) & (0.6,0.3,0.4) & (0.3,0.4,0.2) & (0.7,0.6,0.1) \\ (0.5,0.2,0.1) & (0.6,0.3,0.1) & (0.7,0.6,0.1) & (0.5,0.8,0.1) \end{bmatrix}$$

Initially, $\omega_4 = max\{\omega_1, \omega_2, \omega_{3,}\omega_4\}$, and by choosing vector $\omega = (0.2,0.1,0.3,0.4)^T$ and the reference attribute weight $\omega_r = 0.4$, the relative weights are determined as follows: $\omega_1 = 0.75, \omega_{2,} = 0.5, \omega_{3,} = 0.25, \omega_4 = 1$ and $\theta = 1.5$

Dominance matrix is given as:

$$\emptyset_j = \left[\begin{bmatrix} 0 & \cdots & \emptyset_1(A_1, A_m) \\ \vdots & \ddots & \vdots \\ \emptyset_1(A_m, A_1) & \cdots & 0 \end{bmatrix}\right]$$

$$\emptyset_1 = \begin{bmatrix} 0 & 0.273 & -0.146 & -0.342 & -0.253 \\ 0.341 & 0 & 0.2886 & 0.2581 & 0.129 \\ 0.182 & 0.230 & 0 & -0.309 & -0.253 \\ 0.428 & 0.206 & 0.387 & 0 & 0.129 \\ 0.316 & 0.103 & 0.258 & -0.231 & 0 \end{bmatrix}$$

$$\emptyset_2 = \begin{bmatrix} 0 & 0.253 & 0.279 & 0.236 & 0.2113 \\ 0.211 & 0 & 0.316 & 0.235 & 0.210 \\ -0.334 & 0.126 & 0 & 0.3577 & 0.283 \\ -0.283 & 0.2828 & 0.298 & 0 & 0.183 \\ -0.253 & 0.103 & 0.235 & -0.219 & 0 \end{bmatrix}$$

$$\emptyset_3 = \begin{bmatrix} 0 & -0.593 & -0.593 & -0.4 & -0.432 \\ 0.247 & 0 & 0.438 & 0.182 & 0.197 \\ 0.247 & 0.182 & 0 & 0.211 & 0.166 \\ 0.1666 & -0.438 & 0.506 & 0 & -0.473 \\ 0.182 & -0.473 & -0.4 & 0.197 & 0 \end{bmatrix}$$

$$\emptyset_4 = \begin{bmatrix} 0 & -0.297 & -0.297 & -0.2 & -0.219 \\ 0.494 & 0 & 0.219 & 0.365 & 0.394 \\ 0.494 & 0.365 & 0 & 0.421 & 0.333 \\ 0.333 & -0.219 & 0.253 & 0 & -0.236 \\ 0.365 & -0.236 & -0.2 & 0.394 & 0 \end{bmatrix}$$

Based on $\emptyset_j$, the overall dominance degree is calculated according to the following expression: $\delta(A_i, A_j) = \sum_{z=1}^{n} \emptyset_z(A_i, A_j), i, j = 1,2,3, \dots .. m$, yielding:

$$\delta = \begin{bmatrix} 0 & -2.264 & -0.772 & -0.871 & -0.926 \\ 1.752 & 0 & 0.027 & 1.459 & 1.339 \\ 0.302 & 0.112 & 0 & -0.429 & -0.152 \\ 0.529 & -1.867 & 0.089 & 0 & -0.688 \\ 0.541 & -1.493 & -0.270 & 0.119 & 0 \end{bmatrix}$$

Then the values of $\delta(Ai), i = 1,2,3,4,5$ are as follows:

$$\delta(A1) = 0, \delta(A2) = 1, \delta(A3) = 0.495, \delta(A4) = 0.307, \delta(A5) = 0.396$$

We get the order of $\delta(Ai)$ as: $\delta(A2), \delta(A3), \delta(A5), \delta(A4), \delta(A1)$.
Table 1 gives values of the aggregation operators corresponding attributes.

Table 1 Score value of SVNWA and SVNGA

	SVNWA	SVNGA
A1	(0.711,0.188,0.008)	(0.0720,0.8926, -0.4437)
A2	(0.985,0.005,0.002)	(0.3145,0.5157,0.1822)
A3	(0.998,0.077,0.002)	(0.748,0.834,0.086)
A4	(0.721,0.003,0.075)	(0.101,0.232,0)
A5	(0.968,0.089,0.031)	(0.854,0.284,0)

Table 2 shows the score function of emerging values corresponding to attributes.

Table 2 Score function of the emerging values

	SVNWA	SVNGA
A1	0.663354	-0.44372
A2	0.986081	0.050355
A3	0.921302	-0.00262
A4	0.819463	0.31903
A5	0.878935	0.642449

Table 3 shows the order of the TODIM and aggregation operator.

Table 3 Order of the emerging technology enterprises

	Order
TODIM	$\delta(A2), \delta(A3), \delta(A5), \delta(A4), \delta(A1)$
SVNWA	$\delta(A2), \delta(A3), \delta(A5), \delta(A4), \delta(A1)$
SVNMG	$\delta(A2), \delta(A5), \delta(A4), \delta(A3), \delta(A1)$

8. Comparative Analysis

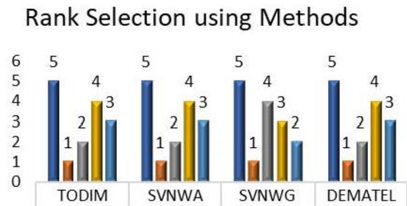
Table 4 compares the suggested method to other methods already in use [105] according to the value of DEMATEL method.

Table 4 Comparison between the proposed and existing methods

	ORDER
TODIM	$\delta(A2), \delta(A3), \delta(A5), \delta(A4), \delta(A1)$
SVNWA	$\delta(A2), \delta(A3), \delta(A5), \delta(A4), \delta(A1)$
SVNMG	$\delta(A2), \delta(A5), \delta(A4), \delta(A3), \delta(A1)$
DEMATEL	$\delta(A2), \delta(A3), \delta(A5), \delta(A4), \delta(A1)$

In Table 4 the biggest hurdle is the ability to accept and adapt to barriers. Experts have confirmed this, saying that while new technology and working methods like co-working with robots are anticipated to become standard in Industry 5.0 in the future, people should be open to them. To cut costs and save time, Industry 5.0 can opt to replace people with machines. The fear of being replaced by more effective machines and robots may make people resistant to the aforementioned solution. The second in the causative group is the legal and regulatory obstacle. According to experts, while most countries have basic laws and regulations in place surrounding the last industrial revolution, legislation regarding specific advancements in Industry 5.0 needs to be implemented. Industry 5.0 refers to newer, more intelligent working methods and technologies, such as digital twins, drone technology, and connected, intelligent equipment. These barriers are influenced by the ones we have just talked about. The influencing group is closest to the barrier regional disparity. This means that of all the cause group obstacles, it has the least impact. Urban and rural areas are increasingly separated by socio-economic and technological barriers, which may result in uneven adoption of Industry 5.0 principles. Security and privacy are the next group to take impact. Data exchange through third-party interfaces, according to industry analysts, will cause privacy and security problems, especially if it falls into the hands of people who have bad intentions. It is necessary to have authentication, access rights, audit, and authentication controls in place, but doing so cannot jeopardize the ecosystem's overall effectiveness.

We have looked at the obstacles so far, but it is also critical to consider the solutions to problems that have been found. Fig. 5 depicts the rank selection by using the following methods: TODIM, SVNWA, SVNWG and DEMATEL. It reveals that the ranking of results is marginally different because of the legal and regularity cost and funding and ethical concerns.



	TODIM	SVNWA	SVNWG	DEMATEL
Regional disparity,Scalability,upskilling reskillinmg and talent retension	5	5	5	5
Acceptance and adaptability	1	1	1	1
Legal and regulatory	2	2	4	2
Cost and funding	4	4	3	4
Ethical concerns	3	3	2	3

Fig. 5 Rank selection for barriers through the methods

The Neutrosophic TODIM approach, however, can choose the businesses in a reasonable manner. The proposed method indicates that the best barriers in context with industry 5.0 deal with indeterminacy. This demonstrates the effectiveness and logic of the strategy we suggested.

9. CONCLUSIONS

From the study above, it is clear that the two operators have almost identical barriers, with a few minor differences. However, the SVN TODIM technique can accurately portray how boundaries in Industry 5.0 are decided. DEMATEL approaches do not handle ambiguity. Neutrosophic TODIM is, therefore, a realistic and efficient method of choosing the barriers. This work identifies, picks out, ranks, and mitigates the obstacles that stand in the way of effective implementation of Industry 5.0. In order to achieve this, we conducted a thorough review of the available literature to identify common hurdles to Industry 5.0 and evaluated the findings with fourteen experts. We ultimately identified eight broad-level barriers. We categorise the eight barriers that have been found into three groups: the prominent group, the cause or influencing group, and the effect group through a rigorous procedure that includes the application of the Neutrosophic single valued TODIM technique from the perspective of the multi-criteria decision-making approach. Also, we rank these obstacles among the relevant groups and compare DEMATAL techniques. From our analysis, due to their propensity to interact with other barriers the most, the obstacles that belong to the prominent category require immediate attention. The barriers in this category, listed in decreasing order of importance, are A4 (cost and funding) and A5 (scalability) (upskilling, reskilling, and talent retention). Similar to how they significantly affect the other obstacles, the cause group's barriers must also be considered. In descending order of importance, the most significant obstacles in this category are A1 (acceptance and adaption), and A2 (legal and regulatory), showing that they were most affected by the other hurdles. We understand the limits of our research. Secondly, the eight implementation barriers for Industry 5.0 have been narrowed down based on prior research and industry reports involving established countries. Although these barriers would be similar to those in developing economies, we acknowledge that emerging countries could need to concentrate more on some particular barriers than others. To overcome the abovementioned constraint, we presented the obstacles to industry and academic professionals who made small suggestions for terminology adjustments to better fit the Indian context, somewhat attesting to the barriers' applicability. Second, the idea of Industry 5.0 is still extremely new and is developing. Depending on the market sector and economy, these obstacles may change. Thirdly, we employed the well-liked MCDM technique of Neutrosophic TODIM for this study's research methodology. Nevertheless, the grey-Neutrosophic TODIML methodology may be applied in the industry 5.0 environment to eliminate fuzziness and indeterminacy because it is changing and uncertain.

We recommend that future scholars examine the correlation between Industry 5.0 restrictions in other developed countries and the findings of our study. A longitudinal assessment of the potential barriers may also be conducted to determine whether the potential barriers have changed over the development of Industry 5.0. Finally, given the notion's immature, constantly changing, and dynamic character, future researchers may employ the Neutrosophic Markov models' technique to remove the ambiguity, indeterminacy, and fuzziness inherent in studying Industry 5.0. Further research can evaluate the interrelationships found in this study using statistical research techniques to assess 5.0 adaptability. We recommend that future work scholars examine the correlation between Industry 5.0 restrictions in other developed countries and the findings of our study. A longitudinal assessment of the potential barriers may also be conducted to determine whether the potential barriers have changed over Industry 5.0's5.0's development. Last but not least, from a methodology standpoint, given the immature, dynamic, and always-growing nature of the notion, future researchers may employ the Plithogenic sets and grey-DEMATEL technique to remove uncertainty and fuzziness inherent while investigating Industry 5.0.

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