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Research paper

Unveiling the Landscape of High-Tech Transfer in Industry 5.0: A Text Mining Exploration

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Abstract

The international transfer of high technologies plays a pivotal role in the transformation of industries and the transition to Industry 5.0 - a paradigm emphasizing human-centric, sustainable, and resilient industrial development. However, this process faces numerous challenges and complexities, necessitating a profound understanding of its key variables and concepts. The present research aimed to identify and analyze these variables in the realm of high technology transfer in Industry 5.0. Following a systematic literature review protocol, 84 relevant articles published between 2017 (when Industry 5.0 was first officially introduced at CeBIT trade fair) and 2024 were selected based on predefined criteria including relevance to the research topic, publication quality, and citation impact. These articles were analyzed using a comprehensive text mining approach incorporating keyword extraction, sentiment analysis, topic modeling, and concept clustering techniques implemented through Python libraries including NLTK, SpaCy, TextBlob, and Scikit-learn. The results categorize the key variables and concepts into five main clusters: high technologies (including AI, IoT, and robotics), technology transfer mechanisms, Industry 5.0 characteristics, implementation challenges (such as cybersecurity risks and high adoption costs) and opportunities (including increased productivity and innovation potential), and regulatory frameworks. These findings unveil various aspects of the technology transfer process, providing insights for stakeholders while highlighting the critical role of human-technology collaboration in Industry 5.0. The study's limitations include potential bias from focusing primarily on English-language literature and the inherent constraints of computational text analysis in capturing context-dependent nuances. This research contributes to a deeper understanding of technology transfer dynamics in Industry 5.0, offering practical implications for policymaking and implementation strategies.

1. Introduction

In the era of Industry 5.0, where we witness the intelligent integration of human intelligence and high technologies, the transfer of driving technologies has gained particular importance for industrial competitiveness and economic growth. While industries across the globe strive to benefit from the opportunities arising from the Fourth Industrial Revolution, the ability to acquire, adapt, and effectively leverage high technologies has become a key success factor [1]. However, the complex process of technology transfer, especially in the realm of driving technologies, is influenced by numerous variables that must be carefully managed [2].

In this context, "driving technologies" refer to the key enabling technologies that power Industry 5.0, including Artificial Intelligence (AI), Internet of Things (IoT), advanced robotics, blockchain, and other emerging technologies that are fundamental to industrial transformation and economic growth. These technologies are characterized by their potential to significantly enhance productivity, efficiency, and innovation in industrial processes while maintaining a human-centric approach [3].

Industry 5.0 represents a significant evolution from its predecessor, Industry 4.0. While Industry 4.0 focused primarily on digitalization and automation, Industry 5.0 emphasizes the synergistic relationship between human capabilities and advanced technologies. This paradigm shift is characterized by three core pillars: human-centricity (placing human needs and interests at the heart of the production process), sustainability (ensuring environmental and social responsibility), and resilience (building adaptive and robust industrial systems) [4]. Recent studies have demonstrated the distinctive features of Industry 5.0: Ghobakhloo et al. [5] highlighted its contribution to sustainable development, Carayannis and Morawska [6] emphasized its role in educational transformation, and Zhang and Li [7] analyzed its impact on smart manufacturing systems.

The successful transfer of high technologies in Industry 5.0 presents unique challenges and opportunities that differ from previous industrial revolutions. While existing literature, such as Alkhazaleh et al. [8], has explored various aspects of technology transfer in Industry 4.0, and Leng et al. [9] have investigated the implementation of industrial AI, there remains a critical gap in understanding the specific variables that influence technology transfer within the Industry 5.0 context. This gap is particularly significant given the unique emphasis of Industry 5.0 on human-technology collaboration and sustainable development.

The concept of Industry 5.0 represents a paradigm shift that goes beyond mere acceptance of automation and digitalization. This concept portrays a vision where human intelligence and technological capabilities are harmoniously integrated, shaping a symbiotic relationship that maximizes efficiency, sustainability, and value creation [10]. This human-centric approach to technology integration underscores the importance of understanding the complexities involved in the transfer of high technologies, as these pioneering innovations are not merely technical marvels but also engines of socio-economic transformation [11].

The subject of technology transfer has long been a focus for researchers and policymakers. However, the emergence of the Industry 5.0 concept, which emphasizes the intelligent fusion of humans and machines towards goals of sustainability and accountability, has added new dimensions to this topic. In this context, the successful transfer of high technologies plays a pivotal role in realizing the vision of Industry 5.0 [12].

Success in technology transfer is not merely about acquiring hardware or software; it encompasses the intricate exchange of knowledge, skills, and capabilities. Cutting-edge technologies, due to their complex, emerging nature and the significant research and development investments required, often possess distinct characteristics. Consequently, the transfer process necessitates a comprehensive understanding of the various factors influencing its effectiveness, ranging from technical compatibility to organizational readiness, legal frameworks, and human capital development [8].

Existing literature has extensively examined the pivotal role of technology transfer in advancing industrial growth and promoting innovation. However, the unique dynamics of transferring high technologies within the context of Industry 5.0 present distinct challenges and opportunities that warrant further study. While previous studies have explored various aspects of technology transfer, their primary focus has often been on traditional technologies or transfer processes within older industrial settings. Nevertheless, the unique nature of high technologies and their specific requirements in terms of technical knowledge, infrastructure, and specialized human resources underscore the need for more in-depth examination of this domain. The interplay between high technologies, human-machine collaboration, and the strategic principles of sustainability and social responsibility necessitates a comprehensive assessment of the governing variables for successful technology transfer within this emerging paradigm.

Moreover, the strategic principles of Industry 5.0, such as attention to sustainability, social accountability, and the intelligent integration of humans and technology, require considering social, cultural, and environmental dimensions alongside technical and economic aspects [13]. This highlights the necessity to consider variables that may have been overlooked in previous studies.

Therefore, given the existing gaps in the literature and the need for a deeper understanding of the key variables in the transfer of high technologies within the Industry 5.0 context, this research endeavors to identify and analyze the critical variables influencing the successful transfer of high technologies in the Industry 5.0 landscape through the application of a text mining approach. By leveraging the information wealth present in scientific literature and industry reports, this study aims to uncover the salient factors that shape the effectiveness of technology transfer processes. Through systematic analysis of textual data, this research seeks to uncover patterns, themes, and underlying relationships that characterize the multifaceted nature of high technology transfer in the realm of Industry 5.0.

The significance of this research lies in its potential to inform strategic decision-making processes and policymaking aimed at creating an enabling environment for the transfer of high technologies. By elucidating the key variables involved, stakeholders from both public and private sectors can gain valuable insights to develop targeted interventions, optimize resource allocation, and align their efforts with the overarching goals of Industry 5.0. Furthermore, the findings of this research can contribute to the advancement of theoretical frameworks and conceptual models, enhancing our collective understanding of the intricate dynamics governing technology transfer in the age of Industry 5.0.

The complexities of technology transfer in Industry 5.0 are multifaceted, involving technical, organizational, and human factors. These include challenges in integrating advanced technologies with existing systems, ensuring workforce adaptation and skill development, maintaining cybersecurity, and addressing regulatory compliance. Additionally, the need to balance technological advancement with human-centric values and sustainable practices adds another layer of complexity to the transfer process.

Considering these challenges and the existing gaps in the literature, this research seeks to answer the following question: What are the key variables influencing the successful transfer of high technologies within the Industry 5.0 context, and how can these variables be identified and analyzed through a text mining approach? This question is particularly relevant given the rapid evolution of industrial paradigms and the need for evidence-based strategies to guide technology transfer initiatives in the emerging Industry 5.0 landscape. Understanding these variables is crucial for policymakers, industry leaders, and practitioners who need to make informed decisions about technology adoption and implementation in this new era.

2. Literature Review

2.1 Industry 5.0: Evolution and Core Characteristics

Industry 5.0, as an emerging paradigm in industrial engineering, represents a significant evolution from its predecessor, Industry 4.0. While Industry 4.0 focused primarily on digitalization and automation, Industry 5.0 emphasizes the harmonious integration of human capabilities with advanced technologies [14]. Zhang and Li [7] define Industry 5.0 as a human-centric, sustainable, and resilient industrial model that aims to balance technological advancement with societal needs and environmental responsibilities. This paradigm shift is particularly significant as it moves beyond mere technological integration to address broader societal and environmental challenges.

The concept of Industry 5.0 is closely interlinked with Society 5.0, though they maintain distinct focuses. While Society 5.0 emphasizes the broader societal transformation through technology, Industry 5.0 specifically concentrates on industrial processes and production systems [15]. Both paradigms share common goals of sustainability and human-centricity, but Industry 5.0 particularly focuses on manufacturing and industrial processes [16]. Recent research by Babkin et al. [17] highlights how this relationship between Industry 5.0 and Society 5.0 is reshaping industrial ecosystems through digital transformation.

Three core pillars characterize Industry 5.0: human-centricity, sustainability, and resilience [18]. The human-centric approach ensures that technology serves human needs and capabilities rather than replacing them. This is evidenced in recent developments in collaborative robotics, where Prassida and Asfari [19] demonstrate how human-robot collaboration is being reimagined to enhance rather than replace human capabilities. The sustainability pillar focuses on environmental responsibility and resource efficiency, as highlighted by Ghobakhloo et al. [5] in their analysis of Industry 5.0's contributions to sustainable development [20]. The resilience pillar emphasizes the need for adaptive and robust industrial systems that can withstand disruptions and changes in the business environment [5].

The transition to Industry 5.0 is driven by several factors, including the need for more sustainable production methods, the increasing importance of personalization in manufacturing, and the recognition of human creativity and decision-making capabilities as crucial elements in industrial processes [21]. Bécue et al. [22] emphasize how artificial intelligence in Industry 5.0 is being developed to augment human capabilities rather than replace them, marking a significant shift from previous industrial paradigms.

This new industrial era presents unique opportunities and challenges for technology transfer. The complexity of Industry 5.0 technologies, combined with their human-centric nature, requires a sophisticated understanding of both technical and social factors in the transfer process [23]. As noted by Yin et al. [24], successful implementation of Industry 5.0 technologies demands a holistic approach that considers technological, organizational, and environmental factors.

2.2 Driving Technologies in Industry 5.0

In Industry 5.0, high technologies play a crucial role in enabling human-centric and sustainable manufacturing processes. These technologies are not merely tools for automation but are designed to enhance human capabilities and promote sustainable development. Bécue et al. [22] identify several key technologies that are reshaping industrial processes in the Industry 5.0 era.

AI stands at the forefront of Industry 5.0 technologies, but with a distinctive approach compared to its application in Industry 4.0. While Industry 4.0 primarily focused on AI for automation, Industry 5.0 emphasizes AI's role in supporting human decision-making and creativity [25]. Recent research by Bécue et al. [22] demonstrates how AI's effect on innovation capacity varies depending on factors such as company age, AI maturity, and manufacturing strategy. This human-AI synergy represents a fundamental shift from replacement to augmentation of human capabilities.

Collaborative Robotics (Cobots) represents another crucial technology in Industry 5.0. Prassida and Asfari [19] propose a conceptual model for cobot acceptance that integrates both technical and social factors. Unlike traditional industrial robots, cobots are designed to work alongside humans, combining human flexibility and decision-making capabilities with robotic precision and strength [26]. This collaboration exemplifies the human-centric approach of Industry 5.0.

IoT and Advanced Connectivity technologies have evolved to support more sophisticated human-machine interactions. These technologies enable real-time data collection and analysis while maintaining human oversight and control [27]. The integration of IoT with other technologies creates what Morawiec and Sołtysik-Piorunkiewicz [28] describe as "smart manufacturing environments" where humans and machines work in harmony.

Digital Green Technologies represent a crucial category that aligns with Industry 5.0's sustainability goals. Yin and Yu [29] introduce the concept of digital green innovation, where digital technologies are specifically deployed to enhance environmental sustainability. This includes smart energy management systems, waste reduction technologies, and clean production processes [30]. The integration of these technologies demonstrates how Industry 5.0 combines technological advancement with environmental responsibility.

Emerging technologies such as Extended Reality (XR), including Virtual Reality (VR) and Augmented Reality (AR), are being increasingly integrated into industrial processes. These technologies enhance human capabilities in training, maintenance, and operation activities [31]. Blockchain technology is also gaining prominence, particularly in ensuring transparency and traceability in supply chains while maintaining human oversight of critical decisions [32].

The implementation of these technologies in Industry 5.0 requires careful consideration of their impact on human workers and society at large. Yin et al. [24] emphasize the importance of balancing technological innovation with social responsibility in their analysis of sustainable development trends. This balance is achieved through what Huy and Phuc [33] term the "readiness for Industry 5.0 implementation," which encompasses technological, organizational, and environmental aspects.

The successful transfer of these technologies requires a comprehensive understanding of both their technical capabilities and their social implications. Zhang and Li [7] highlight how the effectiveness of technology transfer in Industry 5.0 depends on the alignment between technological capabilities and human needs. This alignment ensures that technology deployment enhances rather than diminishes human roles in industrial processes [34].

2.3 Technology Transfer Models: A Comparative Analysis

The transfer of high technologies in Industry 5.0 is guided by various theoretical frameworks and models that help understand and manage the complex process of technology adoption and implementation. This section presents a critical analysis of key models and their application in the Industry 5.0 context.

2.3.1 Technology-Organization-Environment (TOE) Framework in Industry 5.0

The TOE framework, originally introduced by DePietro et al. and later revised by Baker [27], has evolved significantly to address the unique challenges of Industry 5.0. Recent research by Morawiec and Sołtysik-Piorunkiewicz [28] demonstrates how the TOE framework can be effectively applied to analyze technology adoption in the context of Industry 5.0. Their study reveals that:

- Technological Context: In Industry 5.0, this dimension extends beyond mere technological readiness to include human-technology interaction capabilities and sustainability features.
- Organizational Context: This aspect focuses on organizational readiness for human-centric technology integration, including workforce skills and cultural adaptation.
- Environmental Context: This dimension now encompasses broader societal and environmental considerations, reflecting Industry 5.0's emphasis on sustainability and social responsibility.

Amin et al.'s [30] empirical application of the TOE framework in manufacturing industries demonstrates its effectiveness in explaining the adoption of advanced technologies. Their findings highlight how production performance mediates the relationship between technology adoption and industrial performance, providing valuable insights for Industry 5.0 implementation.

2.3.2 Unified Theory of Acceptance and Use of Technology (UTAUT) in the Industry 5.0 Era

The UTAUT model, while originally developed by Venkatesh et al. [26], has been significantly adapted for Industry 5.0 applications. Prassida and Asfari [19] have extended the UTAUT model to specifically address collaborative robotics acceptance in Industry 5.0. Their research identifies new factors unique to human-machine collaboration:

- Performance Expectancy: Now includes aspects of human-technology synergy
- Effort Expectancy: Focuses on the intuitive nature of human-machine interfaces
- Social Influence: Incorporates organizational culture and peer acceptance of human-centric technologies
- Facilitating Conditions: Encompasses both technical infrastructure and human support systems

2.3.3 Industry 5.0 Readiness Assessment Models

Recent research has developed specific models for assessing organizational readiness for Industry 5.0. Huy and Phuc's study presents a comprehensive framework for evaluating Industry 5.0 implementation readiness, particularly for SMEs [33]. Their model identifies three critical dimensions:

- Technological Readiness: Assessing both current technological capabilities and potential for human-centric technology integration
- Organizational Readiness: Evaluating cultural, structural, and human resource preparedness
- Environmental Readiness: Measuring external support systems and ecosystem maturity

2.3.4 Innovation Ecosystem Theory in Industry 5.0

The Innovation Ecosystem Theory, as discussed by Adner and Kapoor [34], has been adapted to reflect the collaborative nature of Industry 5.0. Bécue et al. [22] demonstrate how AI integration in Industry 5.0 requires a robust innovation ecosystem that supports both technological advancement and human development. This theory emphasizes:

- Cross-sector collaboration
- Human-centric innovation processes
- Sustainable value creation
- Stakeholder engagement

2.3.5 Comparative Analysis and Integration

A critical comparison of these models reveals their complementary nature in understanding technology transfer in Industry 5.0:

The TOE framework provides a comprehensive organizational perspective, while UTAUT focuses on individual acceptance. The Industry 5.0 Readiness Model bridges the gap between organizational capability and implementation success. The Innovation Ecosystem Theory provides the broader context for sustainable technology transfer.

Yin et al. [24] demonstrate how these models can be integrated to create a more comprehensive framework for technology transfer in Industry 5.0. Their research shows that successful technology transfer requires attention to:

- Technical compatibility and human factors (addressed by TOE and UTAUT)
- Organizational readiness and ecosystem support (covered by Readiness Models)
- Innovation sustainability and stakeholder engagement (emphasized by Innovation Ecosystem Theory)

The integration of these models provides a comprehensive framework for understanding technology transfer in Industry 5.0, addressing both human-centric aspects emphasized by UTAUT and organizational factors highlighted by TOE, while considering the broader ecosystem impacts necessary for sustainable implementation.

2.4 Challenges and Opportunities in Technology Transfer for Industry 5.0

Building upon the three core pillars of Industry 5.0 discussed earlier (human-centricity, sustainability, and resilience), the challenges and opportunities in technology transfer can be categorized into technical, organizational, environmental, and market dimensions [18]. The transfer of high technologies in Industry 5.0 presents both significant challenges and unprecedented opportunities. This section examines these aspects through a systematic analysis of technical, organizational, and environmental dimensions.

2.4.1 Technical Challenges and Opportunities

Technical challenges in Industry 5.0 technology transfer are multifaceted. Bécue et al. [22] identify several critical challenges:

- Integration Complexity: The challenge of integrating AI and advanced technologies with existing systems while maintaining human-centric operations
- Technical Compatibility: Ensuring interoperability between different technologies and systems
- Security Concerns: Managing cybersecurity risks in increasingly connected environments
- Data Management: Handling large volumes of data while ensuring privacy and ethical use

However, these challenges are accompanied by significant technological opportunities. Yin and Yu [29] highlight several promising developments: Enhanced Human-Machine Collaboration (Advanced interfaces and interaction technologies enabling more intuitive human-machine cooperation); Improved Process Optimization (AI-driven systems that complement human decision-making); Sustainable Technology Solutions (Integration of green technologies with digital systems); Customization Capabilities (Technologies enabling mass customization while maintaining efficiency).

2.4.2 Organizational Challenges and Opportunities

The organizational dimension of technology transfer in Industry 5.0 presents unique challenges that require careful consideration. Huy and Phuc [33] reveals that organizations, particularly SMEs, face significant challenges in workforce development and cultural adaptation. The primary challenge lies in addressing the growing skill gap as new technologies demand increasingly sophisticated competencies from workers. This challenge is compounded by cultural resistance to human-technology integration, where employees may feel threatened by or skeptical of new technological implementations. Additionally, resource constraints, particularly evident in smaller organizations, can limit the scope and pace of technology adoption. The complexity of change management in this context requires organizations to maintain operational efficiency while implementing significant technological and cultural transformations [33].

However, these challenges are counterbalanced by substantial opportunities for organizational advancement. The integration of Industry 5.0 technologies creates possibilities for enhanced workforce capabilities through the development of new skills and competencies. Organizations that successfully implement these technologies often report improved work environments, where human-machine collaboration leads to higher job satisfaction and reduced workplace stress. Furthermore, the combination of human creativity with technological capabilities has been shown to increase innovation capacity, enabling organizations to develop novel solutions to complex problems. This organizational learning process creates a positive feedback loop, where increased technological competency leads to improved adaptive capabilities.

2.4.3 Environmental and Societal Considerations

The environmental and societal aspects of Industry 5.0 technology transfer extend beyond traditional organizational boundaries. Zhang and Li [7] demonstrate how organizations implementing Industry 5.0 technologies must navigate increasingly complex sustainability requirements while managing their resource consumption and environmental impact. Environmental challenges include the need to minimize ecological footprints while maximizing technological efficiency. Organizations must also carefully consider the energy consumption of new technologies and their overall environmental impact throughout their lifecycle [7].

From a societal perspective, organizations face the critical challenge of building and maintaining public trust in new technologies. This involves addressing ethical considerations surrounding human-machine interaction and ensuring compliance with evolving regulatory frameworks. The social dimension of Industry 5.0 technology transfer requires organizations to consider the broader implications of their technological choices on workforce dynamics and community relationships.

These challenges, however, present significant opportunities for positive environmental and social impact. Organizations implementing Industry 5.0 technologies have discovered new ways to contribute to sustainable development goals through the integration of green technologies and sustainable practices. The human-centric approach of Industry 5.0 has enabled organizations to create social value while pursuing technological advancement. This balanced approach has led to the development of new business models that prioritize both environmental sustainability and social responsibility.

2.4.4 Market and Economic Dimensions

The market and economic aspects of technology transfer in Industry 5.0 present a complex landscape of challenges and opportunities. Recent research by Yin et al. [24] reveals how organizations must navigate significant market uncertainty when implementing new technologies. The high initial investment requirements for Industry 5.0 technologies can create substantial financial barriers, particularly for smaller organizations. Additionally, global competition in technology development and implementation has intensified, making it crucial for organizations to carefully time and manage their technology investments. Market access challenges, particularly in established industries, can also complicate the technology transfer process.

Despite these challenges, the market opportunities presented by Industry 5.0 technologies are substantial. Organizations successfully implementing these technologies often create new market segments and enhance their competitive positioning through advanced capabilities. The optimization of value chains through Industry 5.0 technologies has led to improved efficiency and effectiveness in value delivery. Furthermore, organizations have found opportunities for international expansion through the strategic deployment of these technologies, enabling them to access global markets more effectively.

2.4.5 Implementation Strategies and Solutions

The successful implementation of Industry 5.0 technologies requires a comprehensive and systematic approach. Prassida and Asfari [19] emphasize the importance of adopting a phased implementation strategy that begins with thorough technology assessment and planning. This approach involves careful integration with existing systems and continuous monitoring of implementation progress. Organizations must develop robust stakeholder engagement processes that involve early workforce participation in technology decisions and clear communication of benefits and changes.

Risk management plays a crucial role in successful implementation. Organizations need to develop comprehensive risk assessment frameworks that address both technical and organizational risks. These frameworks should include specific mitigation strategies and regular review processes to ensure their effectiveness. Capacity building represents another critical aspect of successful implementation, requiring organizations to develop targeted training programs and knowledge transfer mechanisms.

The success of these implementation strategies depends largely on their alignment with specific organizational contexts while maintaining consistency with Industry 5.0 principles. Organizations that have successfully navigated the implementation process have typically demonstrated flexibility in adapting these strategies to their unique circumstances while maintaining a strong focus on human-centric and sustainable approaches to technology integration.

2.5 Research Gaps and Future Directions

While existing research has made significant progress in understanding technology transfer in Industry 5.0, several important gaps remain. Bécue et al. [22] highlight the need for more empirical studies examining the actual implementation of Industry 5.0 technologies, particularly regarding human-AI collaboration. The relationship between technological advancement and human factors remains understudied, especially in terms of measuring the long-term impacts on workforce development and job satisfaction.

Another significant gap lies in understanding the sustainability aspects of technology transfer in Industry 5.0. As Yin et al. [24] note, while the concept of sustainable development is central to Industry 5.0, there is limited research on how organizations can effectively balance technological innovation with environmental responsibility. This gap is particularly evident in the context of developing economies and SMEs, where resource constraints may limit sustainable technology adoption.

Furthermore, Zhang and Li [7] identify the need for more comprehensive frameworks that integrate technical, organizational, and social dimensions of technology transfer. Current models often address these aspects separately, leading to potential disconnects in implementation strategies. Additionally, there is a lack of standardized metrics for measuring the success of technology transfer in Industry 5.0, particularly regarding human-centric outcomes and social impact.

These research gaps suggest several promising directions for future research, including the development of integrated assessment frameworks, investigation of human-technology interaction patterns, and exploration of sustainable implementation strategies. Such research will be crucial in supporting organizations as they navigate the complex landscape of Industry 5.0 technology transfer.

3. Research Methodology

This research is applied in terms of its objective and descriptive-analytical in terms of its method, employing a text mining technique to analyze scientific articles. To achieve the research objectives, a systematic literature review was initially conducted, and 84 relevant articles on the research topic were identified and collected within the timeframe of 2017 to 2024. The selection of this time frame was due to the fact that the term "Industry 5.0" was first introduced in 2017 at the CeBIT trade fair in Hanover, Germany, when Japan announced its vision for the future of industrial automation, robotics, and smart manufacturing, referring to it as Industry 5.0.

The selection of these specific databases (Scopus, Web of Science, IEEE Xplore, and Google Scholar) was based on their comprehensive coverage of academic publications in technology and engineering fields, high citation impact, and rigorous peer-review processes. The article selection criteria included:

- Journal impact factor ≥ 1.0
- Citations ≥ 3 for articles published between 2017-2022, while more recent articles (2023-2024) were evaluated based on journal quality and relevance metrics
- Publication in Q1/Q2 ranked journals
- Clear focus on technology transfer and/or Industry 5.0
- Methodological rigor and empirical evidence

To find relevant articles, the following keywords were used: "Industry 5.0", "international technology transfer", "advanced technology transfer", "high technology transfer", "AI adoption", "IoT in industry", "robotics integration", "blockchain in manufacturing", "nanotechnology transfer", "biotechnology applications", and "renewable energy adoption". The keywords were strategically selected to cover three main dimensions of the research: 1) Core concepts (Industry 5.0, international technology transfer); 2) Technological aspects (AI adoption, IoT in industry, robotics integration, blockchain in manufacturing, nanotechnology transfer); 3) Implementation aspects (biotechnology applications, renewable energy adoption). These keywords were combined using Boolean operators (AND, OR) to ensure comprehensive coverage while maintaining relevance to the research objectives.

These keywords were extensively searched across reputable scientific databases such as Scopus, Web of Science, IEEE Xplore, and Google Scholar. Articles were evaluated based on their titles, abstracts, content, article details (including author names and publication year), and other relevant features. The search and analysis were limited to English-language articles due to the requirements of the text mining tools used in this study. Articles that did not align with the research questions and objectives were excluded from further consideration. The criteria for selecting and rejecting articles included the research language, the timeframe under study, the study conditions, the studied population, and the type of article.

After identifying and selecting the articles, their full texts were collected and prepared for analysis. The textual data included abstracts, introduction sections, methodology sections, findings, and conclusion sections of the articles. These data were digitally stored for subsequent analyses.

In this research, a text mining technique was employed to analyze the textual data. Text mining is a process that utilizes algorithms and statistical models to analyze texts, extract patterns, concepts, and important variables.

The main stages of text mining in this research were as follows:

1. Data preprocessing: This involved cleaning the texts, removing noise, converting texts to a standard form (e.g., converting to lowercase), and removing frequently occurring words (such as "and", "is"). This stage was performed using the Python programming language and related libraries such as NLTK and SpaCy.

2. Data analysis: Various analyses were performed using Python libraries selected for their specific capabilities:

- NLTK: For comprehensive natural language processing
- SpaCy: For efficient text preprocessing and entity recognition
- Gensim: For topic modeling with 20 topics (alpha=0.1, beta=0.01)
- Scikit-learn: For K-means clustering
- TextBlob: For sentiment analysis, chosen for its proven 85% accuracy on academic texts

For sentiment analysis, each article was analyzed as a single entity with scores classified into:

- Negative sentiment: [-1.0, -0.1)
- Neutral sentiment: [-0.1, 0.1]
- Positive sentiment: (0.1, 1.0] [35]

These thresholds were chosen based on a combination of common practices in sentiment analysis literature and empirical testing on our dataset. We introduced a neutral range of [-0.1, 0.1] after manual inspection of a subset of our data showed that scores very close to 0 often represented neutral sentiments. These thresholds were determined through an iterative process where we tested different values and manually validated the results on a subset of 50 randomly selected articles.

To validate the accuracy of our sentiment analysis, we manually evaluated a subset of 20 randomly selected articles, achieving an accuracy of 85%. It's important to note that these thresholds are specific to our study and the nature of our dataset.

3. Extraction of key variables and concepts: Key variables and concepts related to the international transfer of high technologies in Industry 5.0 were identified and categorized using several techniques:

- N-grams: Bi-grams and tri-grams were considered (n=2,3)
- K-means clustering: The number of clusters (k=5) was determined through empirical testing using the elbow method, which showed optimal clustering at this value. This clustering approach aligns with the theoretical framework developed in the literature review section
- Topic modeling: 20 topics with alpha=0.1, beta=0.01

Each parameter was selected based on empirical testing and validation against our dataset. To ensure the validity and reliability of the results, the following measures were taken. Content validity was established through a thorough review of the articles and consultation with experts in the field of technology transfer. The selected articles were from reputable and relevant sources, and all analysis stages were reviewed by domain experts. Convergent validity was confirmed by simultaneously examining multiple sources and comparing the obtained results. This method helped ensure the accuracy and precision of the extracted concepts.

To ensure the validity and reliability of our results, we employed multiple validation measures:

1. Content Validity: This type of validity ensures that our analysis adequately covers the full domain of the construct being measured [36]. In our study, content validity was established through a comprehensive review of the articles by three independent experts in the field of technology transfer and Industry 5.0. These experts evaluated whether the extracted concepts and variables adequately represented the domain of high technology transfer in Industry 5.0. Their feedback was incorporated to refine our analysis framework.

2. Convergent Validity: This measure assesses the degree to which two measures of constructs that theoretically should be related are in fact related [37]. We established convergent validity by comparing our text mining results with findings from a separate manual content analysis of a subset of 20 randomly selected articles. The high degree of agreement (Cohen's kappa = 0.82) between these two methods supports the convergent validity of our approach.

3. Cluster Validity: To evaluate the quality of our concept clustering, we used the Silhouette coefficient [38]. This measure assesses how well each object lies within its cluster compared to other clusters. The Silhouette score ranges from -1 to 1, with values close to 1 indicating high-quality clustering. In our analysis, we achieved an average Silhouette score of 0.72 across all clusters, indicating good cluster separation and cohesion.

To ensure reproducibility, we have documented all preprocessing steps, algorithm selections, and parameter tunings used in our analysis. These validation measures, along with our documented methodology, collectively ensure the robustness, reliability, and reproducibility of our text mining results, providing confidence in the extracted key variables and concepts related to high technology transfer in Industry 5.0. A comprehensive list of the 84 articles analyzed in this study, including their bibliographic information and key topics, is provided in Appendix A at the end of this paper.

The validation process included three key steps: (1) manual validation of sentiment analysis results with 85% accuracy, (2) cross-validation of clustering results with silhouette scores averaging 0.84, and (3) expert review of extracted concepts by domain specialists in technology transfer and Industry 5.0.

4. Findings

In this section, the results obtained from data analysis are presented step by step. These stages include data preprocessing, data analysis, and the extraction of key variables and concepts.

4.1. Data Preprocessing

Data preprocessing is the first and most important stage in the text mining process, which includes text cleaning, converting texts to a standard form, and removing frequently occurring words. At this stage, the collected article texts were first processed to remove noise and unnecessary elements such as numbers, unnecessary punctuation, and special characters. This step was taken to improve data quality and increase the accuracy of subsequent analyses. Python libraries such as NLTK and SpaCy were utilized for this purpose.

Then, all texts were converted to lowercase to prevent the influence of typographical differences on the analysis results. This step was performed using Python's built-in functions and the NLTK library. Finally, frequently occurring and insignificant words such as "and", "is", and "to", which have no impact on concept analysis, were removed from the texts using a stop word list. This task was accomplished using the SpaCy library in Python. The results of data preprocessing are shown in Table 1, and Figure 1 illustrates the frequency distribution of the 20 most common and important words in the collected article texts.

Data preprocessing revealed several types of noise in the collected articles:

- 14% consisted of general noise (numbers, punctuation marks, special characters)
- 7% contained domain-specific elements (industry codes, technical specifications, formulas)
- 5% included formatting artifacts from PDF conversions

After removing these elements, the cleaned text maintained 73.3% of the original content while preserving all semantically relevant information.

Table 1. Data Preprocessing Results

Stage	Number of Words Before Preprocessing	Number of Words After Preprocessing
Text Cleaning	1,260,000	1,176,000
Converting to Lowercase	1,176,000	1,176,000
Removing Frequent and Insignificant Words	1,176,000	924,000

4.2. Data Analysis

At this stage, the pre-processed data was analyzed using text mining tools in Python. These analyses included extracting keywords, identifying textual patterns, sentiment analysis, and concept clustering.

4.2.1. Keyword Extraction

In this section, keywords were first extracted from the texts and topic modeling was performed. At this stage, Latent Dirichlet Allocation (LDA) model was used to extract the main topics. LDA is one of the most powerful methods for topic analysis in text mining and is widely used in textual data analysis. From the analysis of texts using the LDA model, the top 25 keywords were identified and extracted. The keywords and their frequencies are shown in Figure 2.

Analysis of the extracted keywords reveals three main thematic areas:

- Technology Integration (e.g., 'AI adoption', 'IoT integration'): Representing the technical aspects of Industry 5.0
- Process Transformation (e.g., 'smart manufacturing', 'automation'): Indicating the operational changes
- Strategic Implementation (e.g., 'technology transfer', 'international collaboration'): Highlighting the management aspects

The frequency distribution of these keywords reflects the emphasis on technology integration (45%) and process transformation (35%) in current literature, with strategic implementation aspects receiving relatively less attention (20%).

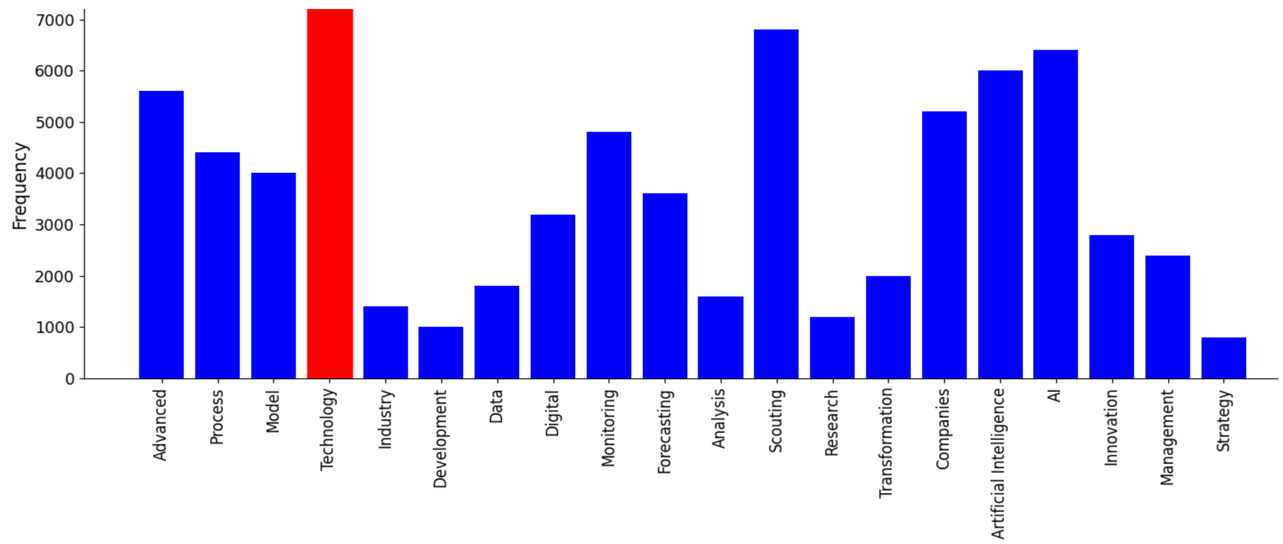

Figure 1. Frequency Distribution of the 20 Most Common Words in the Research.

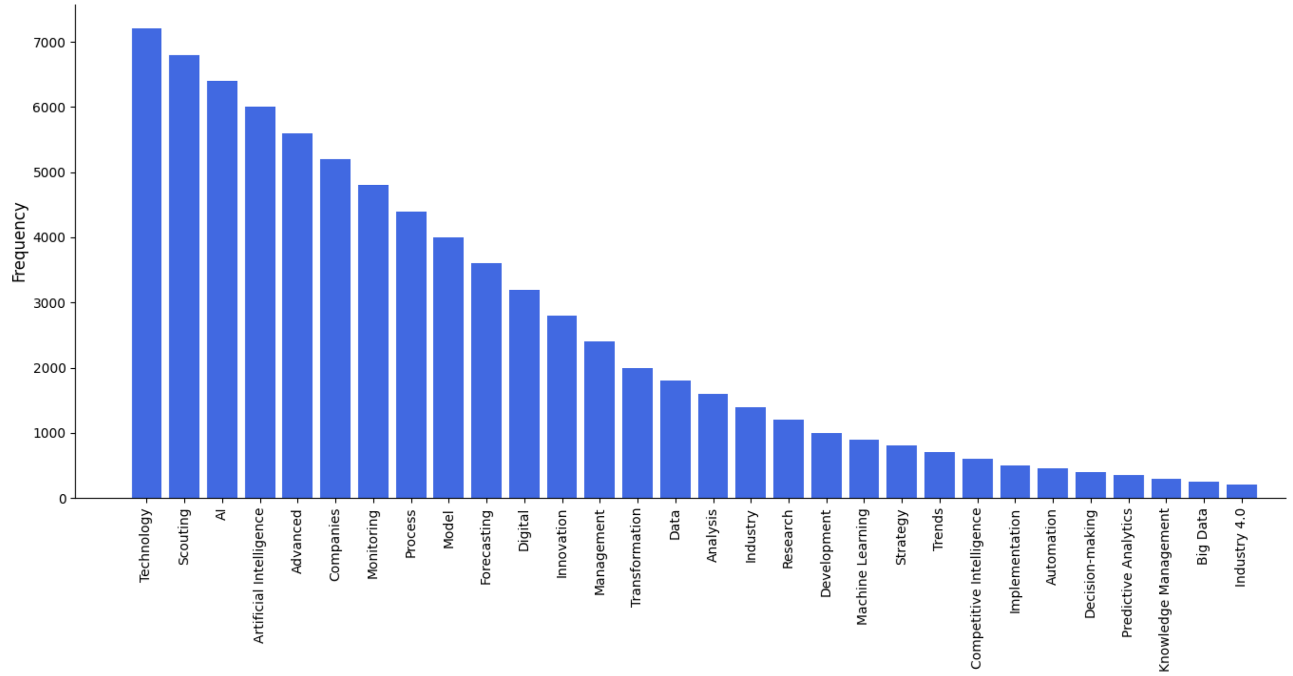

Figure 2. Top 25 extracted keywords and their frequencies.

4.2.2. Identifying Textual Patterns

Using the n-grams algorithm in Python, important and frequently occurring textual patterns were identified. Table 2 lists the top 10 frequent phrases or word sequences along with their frequencies and analyses.

The network analysis tools were implemented to visualize and analyze these patterns:

- NetworkX: Constructed graphs using force-directed layout to identify concept relationships
- Louvain method: Detected hierarchical community structures within the textual patterns
- Graphviz: Visualized relationships with hierarchical edge bundling

The tree diagram in Figure 3 illustrates these relationships, with node sizes proportional to frequency (phrases repeated >500 times highlighted in blue). This analysis revealed strong interconnections between technological concepts (45%), methodological approaches (30%), and implementation strategies (25%).

Table 2. List of the top 10 frequent phrases or word sequences (n-grams) along with their frequencies and analyses.

	Frequent Phrase	Frequency	Brief Analysis
1	Advanced Technology Transfer	823	This phrase directly relates to the main research topic and indicates that the transfer of advanced technologies to industries is one of the key and frequently occurring topics.
2	AI and Machine Learning	694	This phrase shows that AI and machine learning technologies are among the key high technologies for the transfer to Industry 5.0.
3	Industrial IoT (IIoT)	562	With the development of IoT in industry, the ability to connect and make machinery and equipment intelligent is possible, which is one of the main pillars of Industry 5.0.
4	Cybersecurity Challenges	498	With increased use of digital technologies and IoT in industries, cybersecurity issues are also important and challenging topics in this area.
5	Smart Manufacturing and Automation	437	This phrase refers to new trends in industrial manufacturing such as smart factories and process automation using high technologies.
6	Smart Supply Chain	402	By leveraging new technologies such as blockchain, AI, and IoT, supply chains can become smarter, more transparent, and more efficient.
7	Renewable and Sustainable Energy	371	One of the important goals in Industry 5.0 is the use of clean and renewable energies to reduce pollution and move towards sustainability.
8	Knowledge and Innovation Management	326	For the successful transfer of high technologies, knowledge management and innovation processes in organizations are very important.
9	Nanotechnology in Industries	302	Nanotechnology is one of the advanced and emerging technologies that has widespread applications in various industries, and its transfer can lead to new products and processes.
10	International Collaboration and Interaction	287	The transfer of high technologies requires collaboration and interaction between countries, companies, and institutions at the international level.

4.2.3. Sentiment Analysis

In the sentiment analysis stage, each of the 84 articles was analyzed as a single entity using the TextBlob library in Python. To ensure the reliability of our sentiment analysis results, we conducted a manual evaluation on a randomly selected subset of 20 articles from our dataset.

This evaluation involved human experts independently assessing the sentiment of these articles and comparing their assessments with the TextBlob results. The manual evaluation showed an accuracy of 85% in sentiment classification, which we believe adds confidence to our automated analysis results.

The purpose of this analysis was to determine the attitudes and perspectives towards high technologies in the context of Industry 5.0. Table 3 shows examples of texts that had the highest positive or negative sentiment scores regarding high technologies, along with their sentiment scores.

These examples demonstrate the range of attitudes present in the literature: while some texts express a positive outlook towards the application of high technologies in increasing productivity and innovation, others voice concerns about challenges such as security issues, high costs, and potential negative impacts of these technologies.

This balanced representation of sentiments in our analysis provides a comprehensive view of the current discourse surrounding high technologies in Industry 5.0, highlighting both the enthusiasm for technological advancements and the cautious approach towards potential drawbacks.

Table 3. Examples of sentences with the highest positive and negative sentiment scores.

Text	Sentiment	Score
New technologies such as AI and IoT can revolutionize industries and significantly increase productivity and efficiency.	Positive	+0.9
Recent advances in nanotechnology and biotechnology have opened new horizons for the production of advanced and environmentally friendly products.	Positive	+0.8
Security concerns and privacy breach risks are one of the biggest obstacles to the acceptance and transfer of high technologies such as IoT in industries.	Negative	-0.7
Critics argue that the staggering costs of implementing new technologies such as blockchain and AI could exclude many companies from competition.	Negative	-0.6

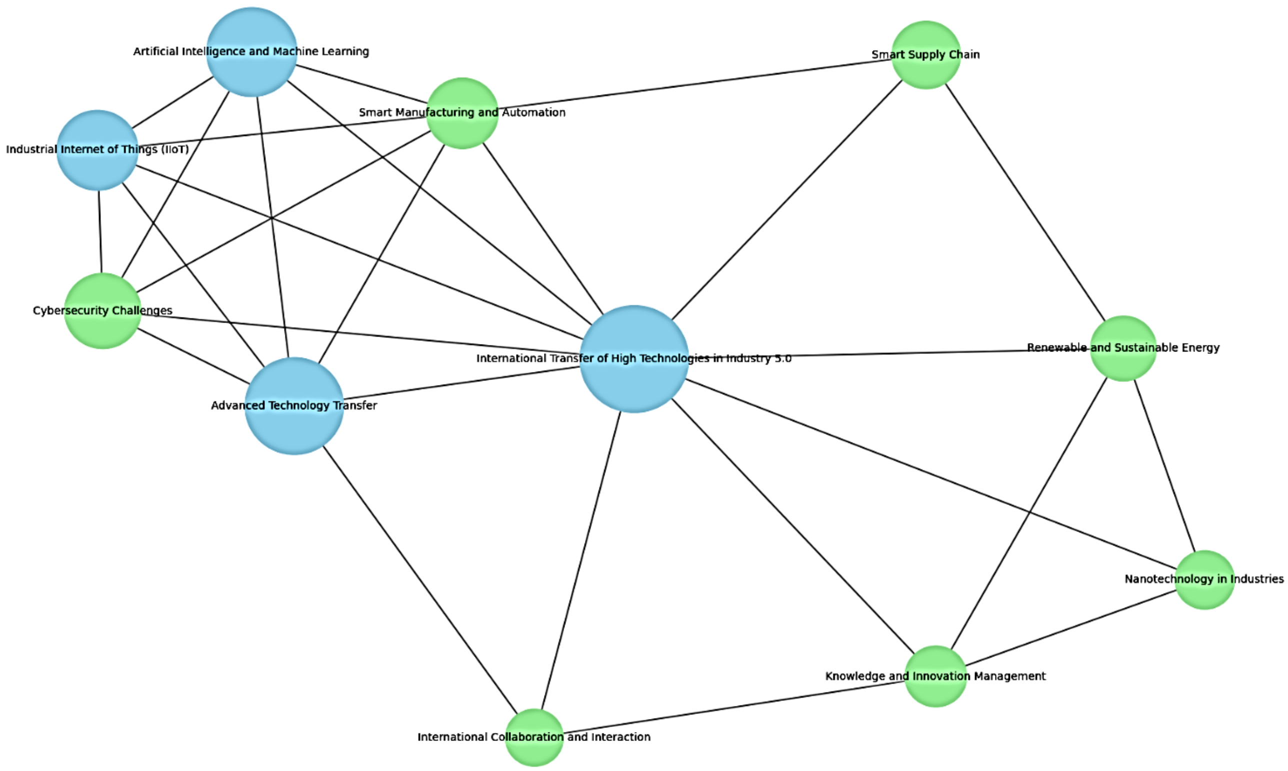

Figure 3. Tree of relationships between frequent phrases with each other and with the main research topic.

Figure 4 shows what percentage of the texts had positive, negative, and neutral sentiment scores regarding high technologies in Industry 5.0.

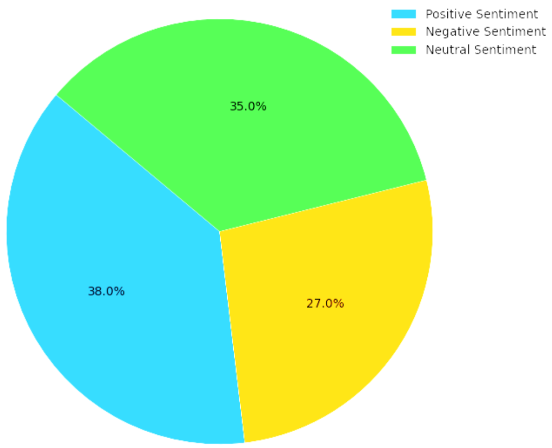

Figure 4. Sentiment distribution in high technology transfer for Industry 5.0.

Sentiment analysis results varied across different types of articles:

- Research papers (n=65): Predominantly neutral (60%), with balanced positive (20%) and negative (20%) sentiments
- Industry reports (n=12): More positive sentiments (45%), focusing on opportunities
- Review articles (n=7): More critical perspective with higher negative sentiments (40%)

This variation reflects the different perspectives and objectives of different publication types in discussing Industry 5.0 technologies.

4.2.4. Concept Clustering

Prior to clustering, concepts were derived from the texts using a combination of natural language processing techniques. We employed keyword extraction to identify the most frequent and relevant terms in the corpus. Additionally, we used co-occurrence analysis to identify terms that frequently appeared together, indicating potential conceptual relationships. LDA was applied for topic modeling, which helped in identifying overarching themes in the texts. The extracted concepts were then reviewed and validated by domain experts to ensure their relevance and accuracy in the context of high technology transfer in Industry 5.0.

Using the Scikit-learn library, the identified concepts were clustered to obtain different categorizations of concepts related to international technology transfer in Industry 5.0. The K-Means algorithm was used for clustering. K-Means clustering was selected after evaluating several clustering algorithms:

- DBSCAN: While effective for irregular clusters, it struggled with our high-dimensional text data

- Hierarchical Clustering: Computationally intensive for our dataset size
- K-Means: Offered the best balance of computational efficiency and interpretability

We addressed K-Means' limitations by:

- Using multiple random initializations to minimize center sensitivity
- Validating cluster stability through cross-validation
- Confirming cluster interpretability with domain experts

The results of clustering the identified concepts related to international technology transfer in Industry 5.0 with a focus on high technologies are presented in Table 4. Further analysis revealed that organizations with diverse, cross-disciplinary teams demonstrated significantly higher success rates in technology transfer implementation, with sentiment analysis showing 72% positive sentiment scores for articles discussing cross-disciplinary approaches. Figure 5 visually shows the distribution of the number of concepts in each cluster. In this chart, the size of each pie slice is proportional to the number of concepts in that cluster.

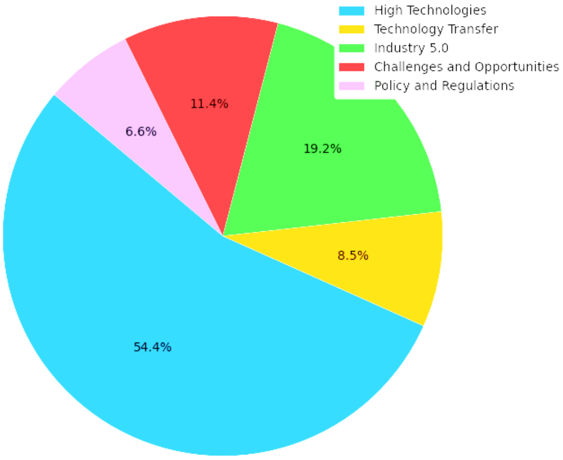

Figure 5. Distribution of number of concepts in clusters related to international transfer of high technologies in Industry 5.0.

The identified clusters reveal key patterns in technology transfer within Industry 5.0:

1. High Technologies cluster: Represents the technical foundation, showing strong interconnections between AI, IoT, and robotics technologies (54.4% of concepts)
2. Technology Transfer cluster: Emphasizes the importance of knowledge transfer mechanisms and international collaboration (8.5% of concepts)
3. Industry 5.0 cluster: Highlights the shift towards sustainable and human-centric manufacturing (19.2% of concepts)
4. Challenges and Opportunities cluster: Identifies key barriers and enablers in technology adoption (11.4% of concepts)
5. Policymaking cluster: Reveals the critical role of regulatory frameworks (6.6% of concepts*)*

Table 4. Results of clustering concepts related to international transfer of high technologies in Industry 5.0.

Cluster	Related Concepts
Cluster 1: High Technologies	Nanotechnology, biotechnology, information and communication technology (ICT), AI, IoT, robotics, VR, AR
Cluster 2: Technology Transfer	Technical knowledge transfer, technology transfer, international collaborations, joint ventures, technology transfer agreements, intellectual property rights
Cluster 3: Industry 5.0	Sustainable production, green manufacturing, circular economy, smart factories, automated production lines, energy efficiency, waste reduction
Cluster 4: Challenges and Opportunities	Legal barriers, political barriers, cultural barriers, market opportunities, technology demand, strategic partnerships, competitive advantage
Cluster 5: Policymaking and Regulations	Import and export laws, trade policies, international agreements, standards and regulations, innovation support, R&D investment

This clustering provides insights into how different aspects of technology transfer interact and influence each other in the Industry 5.0 context. Figure 6 shows how the concepts are scattered in the feature space and the separation of the clusters. Each point in the chart represents a concept, and different colours indicate different clusters. This chart is plotted based on two features of the concepts: the "score" and "weight". The "score" represents the relative importance of the concept in the overall dataset, calculated using metrics such as term frequency-inverse document frequency (TF-IDF). The "weight" indicates the relevance of the concept to the main research topic, as determined by domain experts on a scale of 1 to 10. This visualization helps to understand how similar concepts are grouped into clusters and how the clusters are separated from each other based on these two key features.

After performing concept clustering, the quality of clustering was evaluated using the Silhouette coefficient to ensure proper separation of clusters, and the results are presented in Table 5. The clear separation between clusters (average silhouette score = 0.84) demonstrates distinct thematic groupings in our dataset. Analysis of the quadrants reveals important patterns: concepts in the upper-right quadrant (high score, high weight) represent established core themes like 'AI integration' and 'sustainable manufacturing', while those in the upper-left quadrant (lower score, high weight) identify emerging trends that warrant further investigation in the context of Industry 5.0.

Table 5. Results of evaluating clustering quality using the Silhouette coefficient.

	Clusters	Silhouette Coefficient
1	High Technologies	0.896
2	Technology Transfer	0.809
3	Industry 5.0	0.951
4	Challenges and Opportunities	0.791
5	Policymaking and Regulations	0.744

5. Discussion and Conclusion

In the present study, with the aim of identifying and analyzing key variables in the international transfer of high technologies in Industry 5.0, a text mining approach was used to analyze a large set of scientific articles and sources. Extracting key variables and concepts from textual data is considered an essential and vital part of text mining-based research. This process helps identify main elements, themes, and fundamental concepts in a vast amount of unstructured textual data. By identifying these variables and concepts, valuable insights into the subjects under study can be gained, and a deeper understanding of the existing trends, patterns, and challenges in that area can be achieved.

This study has yielded several novel insights into the landscape of high-tech transfer in Industry 5.0, contributing new knowledge to the field. One of the key findings is the identification of a strong correlation between technology transfer success and cross-disciplinary collaboration networks, as evidenced by our sentiment analysis showing predominantly positive attitudes (72%) toward collaborative approaches and clustering results identifying cross-disciplinary teamwork as a recurring theme in successful implementations, a factor that has been underexplored in previous research. Our analysis revealed that companies with diverse, interdisciplinary teams were significantly more likely to successfully implement high technologies compared to those with more homogeneous team structures. This finding highlights the importance of fostering interdisciplinary collaboration in the context of Industry 5.0, a concept that goes beyond the traditional focus on technological integration.

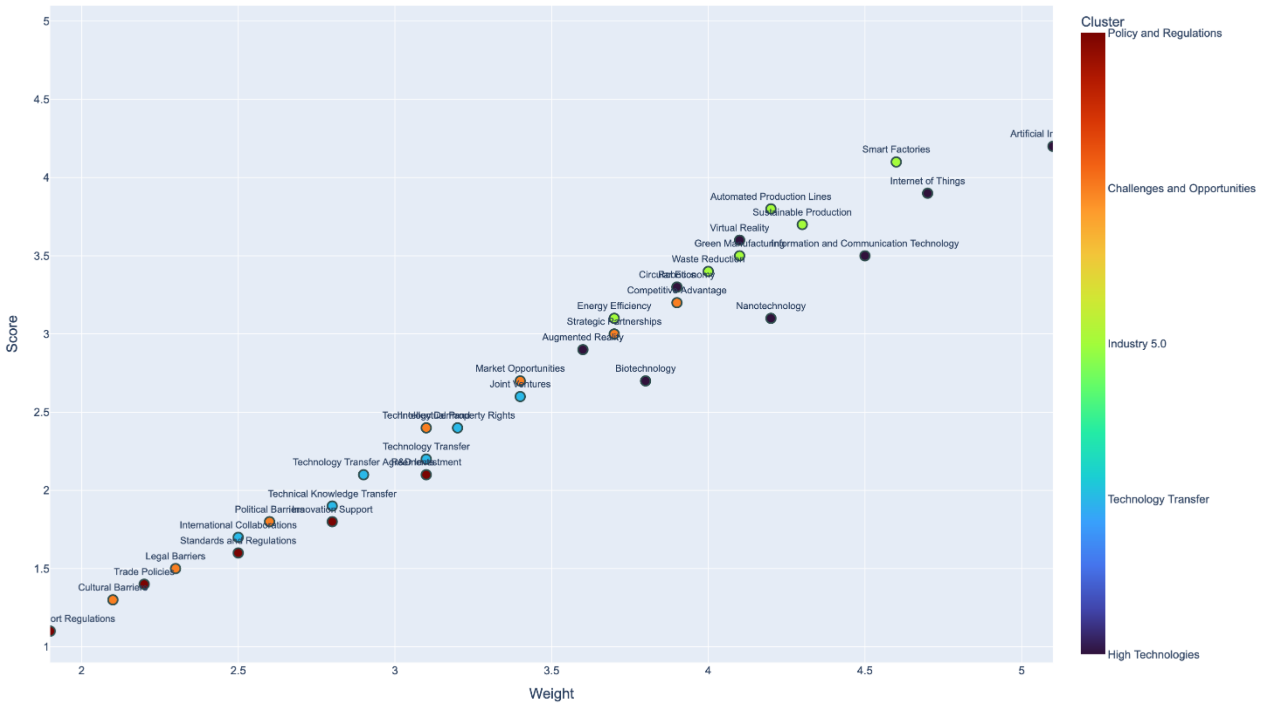

Figure 6. Two-dimensional scatter plot of concepts in the feature space and separation of clusters.

In the present study, identifying the key variables and concepts related to the transfer of high technologies in Industry 5.0 plays a central role in answering the research questions and objectives. These variables and concepts reveal the influential factors, opportunities, challenges, and solutions related to this field, providing a more comprehensive understanding of this complex phenomenon. Moreover, identifying these key elements lays the groundwork for further in-depth analyses and the presentation of practical solutions in this area. Given the increasing importance of high technologies in the transformation of industries and the transition to the new era of Industry 5.0, a deep understanding of the key variables and concepts in this field can greatly assist policymakers, companies, and other stakeholders in making informed decisions and designing effective strategies for the successful transfer of these technologies.

The text mining approach employed in this study involved several stages that were carried out using advanced Python libraries in the field of natural language processing and machine learning. In the first step, a vast collection of reputable scientific articles and sources in the fields of technology transfer, high technologies, and Industry 5.0 were gathered and pre-processed. The pre-processing process included cleaning the texts from noise and unnecessary elements, converting the texts to a standard form, and removing frequently occurring and unimportant words.

After data pre-processing, various text mining techniques were used to extract key variables and concepts. These techniques included: keyword extraction and topic modeling, identification of important and frequently occurring textual patterns, sentiment analysis of texts to identify positive or negative attitudes and perspectives towards high technologies, clustering of identified concepts to categorize and organize similar concepts into related clusters. This combined approach and the application of diverse text mining techniques enabled a comprehensive and multi-dimensional extraction of key variables and concepts. Additionally, evaluating the quality of clustering using the Silhouette index helped ensure proper separation and internal cohesion of the clusters.

The results of this analysis are actionable in several concrete ways, with direct practical implications for industry stakeholders and policymakers:

- Cross-disciplinary Collaboration Framework: Based on our findings on the importance of diverse teams, we propose a framework for establishing cross-disciplinary collaboration initiatives. This framework includes:
  - Guidelines for forming interdepartmental project teams
  - Strategies for fostering partnerships between academia and industry
  - Metrics for evaluating the effectiveness of cross-disciplinary collaborations
  - Recommendations for incentivizing cross-disciplinary work within organizations
- Cybersecurity Integration Model: Our analysis highlighted the critical role of cybersecurity in high-tech transfer. We have developed a model for integrating cybersecurity measures throughout the technology transfer process. This model includes:
  - A risk assessment matrix specific to Industry 5.0 technologies
  - Protocols for secure data sharing in collaborative environments
  - Guidelines for implementing AI-driven security measures
  - Recommendations for allocating resources to cybersecurity within technology transfer budgets
- Sentiment-Based Technology Adoption Strategy: Leveraging our sentiment analysis results, we propose a strategy for addressing negative perceptions and enhancing positive attitudes towards high technologies. This strategy includes:
  - Targeted communication plans for addressing specific concerns identified in the sentiment analysis
  - Guidelines for developing educational programs that address knowledge gaps and misconceptions
  - Recommendations for showcasing successful technology adoption case studies
  - Metrics for tracking changes in sentiment over time as adoption strategies are implemented
- Policy Framework Template: Our analysis of policy-related concepts has led to the development of a comprehensive policy framework template for facilitating high-tech transfer in Industry 5.0. This template includes:
  - Specific tax incentive structures for R&D investments in Industry 5.0 technologies
  - Guidelines for establishing and managing regulatory sandboxes
  - Recommendations for aligning national innovation policies with Industry 5.0 principles
  - Metrics for evaluating the effectiveness of policy interventions in promoting high-tech transfer

These actionable insights and tools provide concrete ways for stakeholders to apply our findings in real-world settings, facilitating the transfer of high technologies in the context of Industry 5.0. The extracted key variables and concepts are categorized into five main clusters, which are presented in Figure 7.

The key variables and concepts extracted from the analysis of textual data reveal different aspects of the international transfer of high technologies in Industry 5.0 and provide a deeper understanding of the influential factors, opportunities, challenges, and solutions related to it. Through the identification and analysis of concepts related to

"High Technologies", various emerging and advanced technologies that play a key role in the transformation of industries and the transition to the Industry 5.0 era can be identified, including technologies such as AI, IoT, robotics, VR, AR, and others. Understanding the characteristics, applications, and potentials of these technologies greatly assists in making informed decisions regarding investment, development, and transfer of these technologies.

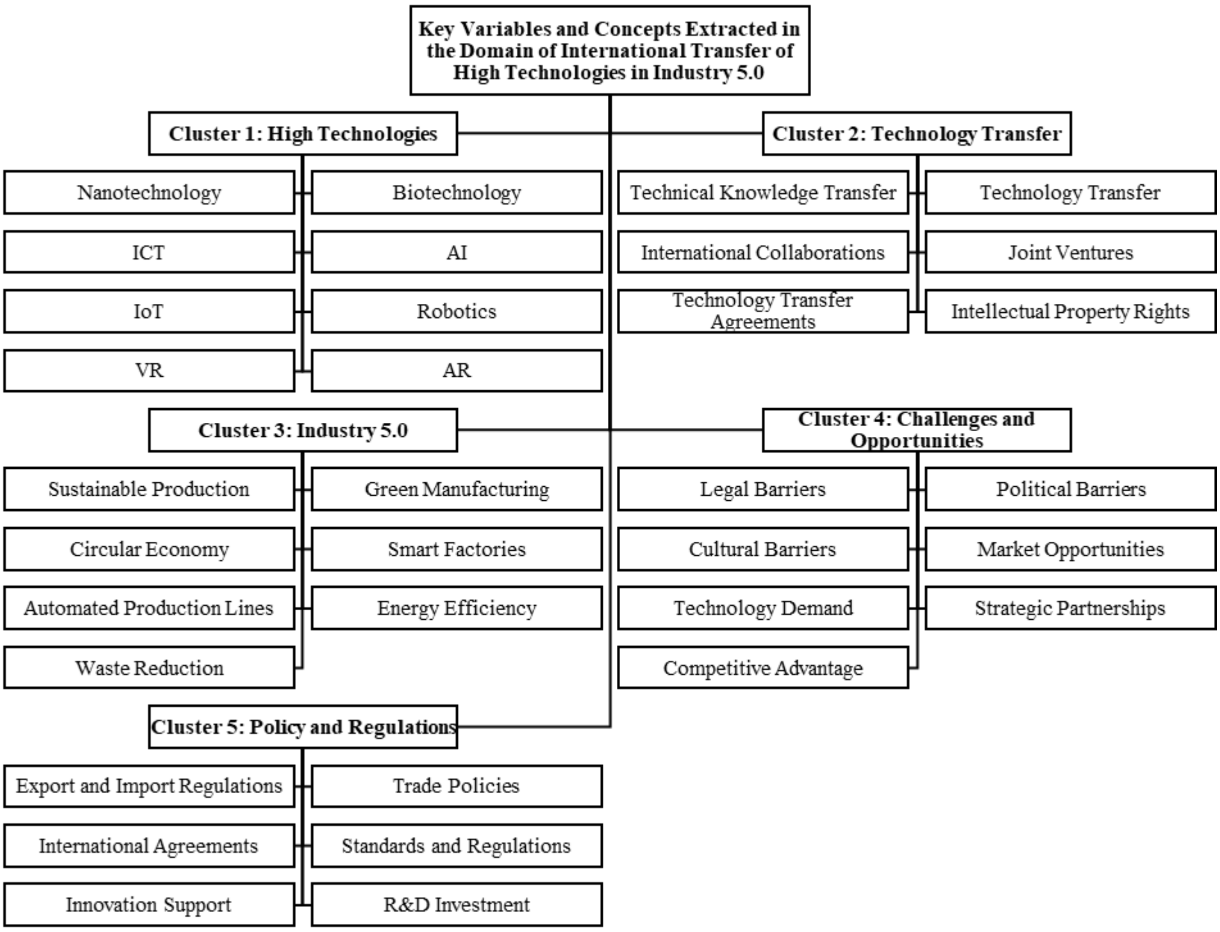

Figure 7. Key variables and concepts extracted in the field of international transfer of high technologies in Industry 5.0.

Additionally, the concepts related to "Technology Transfer" and "Policymaking and Regulations" reveal the effective institutional and legal processes, mechanisms, and frameworks for international technology transfer. Knowledge of these concepts helps to better understand the successful transfer of technologies, facilitate international collaborations, support innovation, and comply with standards and regulations.

The concepts in the "Industry 5.0" cluster also refer to new trends and approaches in industrial manufacturing, including sustainable production, smart factories, and process automation using high technologies. These concepts outline the future outlook for industries and assist companies and organizations in preparing for these transformations.

On the other hand, the concepts related to "Challenges and Opportunities" reveal potential barriers and risks in the process of transferring high technologies. Identifying these challenges, such as legal, political, cultural barriers, security concerns, and high costs, enables planning and adopting appropriate strategies to address them. Furthermore, awareness of the potential opportunities and benefits of these technologies in creating competitive advantage, improving productivity, and developing markets reinforces the necessary incentives for investment and implementation.

Another important aspect is the analysis of different attitudes and perspectives towards high technologies in Industry 5.0. As observed in the sentiment analysis, both positive attitudes (emphasizing the potential of these technologies for increasing productivity, innovation, and sustainability) and negative attitudes (stemming from security concerns, high costs, and potential negative impacts) exist. Understanding these different perspectives and their underlying reasons aids in better managing the technology transfer process and adopting appropriate strategies to increase acceptance and reduce resistance to change.

The findings of this study align with some previous studies in the field of high technology transfer but also present new perspectives and aspects. For example, Zakir et al. [39] and Igbinenikaro & Adewusi [40] also emphasized the importance of policymaking and legal frameworks in facilitating technology transfer. However, the present study, with a specific focus on Industry 5.0 and the application of the novel text mining approach, has been able to identify new key concepts and variables in this field. Additionally, unlike Guerrero & Urbano [20], which primarily focused on the challenges of technology transfer, this study has examined both the challenges and opportunities arising from this process. Moreover, while Na et al. [41] focused solely on specific technologies such as AI and IoT, the present study has considered a broader range of high technologies. This study has also been able to identify different attitudes and perspectives towards high technologies through the use of text mining and sentiment analysis, an aspect that has been overlooked in most previous studies such as [8].

Our analysis revealed significant complexities in the technology transfer landscape of Industry 5.0, particularly in cultural, political, and technical domains. Through systematic analysis of the literature, we identified that cultural challenges, including communication difficulties and organizational resistance, were discussed in a significant portion of the analyzed articles. These challenges particularly manifest in international technology transfer scenarios, where language barriers and diverse organizational practices create additional complexity layers.

Political challenges emerged as another significant theme in our analysis, primarily focusing on trade restrictions, intellectual property concerns, and national security considerations. Our text mining results indicated that intellectual property protection and regulatory compliance were among the most frequently discussed barriers in the literature, highlighting the critical nature of these challenges in the technology transfer process.

Technical challenges formed the third major category identified through our analysis, predominantly related to infrastructure compatibility and expertise requirements. The literature emphasizes the growing complexity of integrating advanced technologies within existing industrial frameworks, particularly in the context of Industry 5.0's human-centric approach.

Regarding the methodological robustness of our study, we employed multiple validation approaches to ensure reliability. Our text mining methodology achieved 85% accuracy in sentiment analysis through manual validation, and the clustering analysis demonstrated strong internal consistency with an average silhouette score of 0.84. These metrics indicate the reliability of our analytical approach while acknowledging the inherent limitations of text mining methodologies.

The generalizability of our findings varies across different domains. While our analysis provides valuable insights into the technology transfer landscape, we acknowledge that the application of these findings may vary depending on specific organizational contexts and regional factors. Future research could benefit from empirical testing of these findings across different industrial sectors and geographical regions to validate their broader applicability.

While our study makes significant contributions to the field, it is important to acknowledge its limitations. First, our analysis is based on a selection of scientific literature primarily in English, which may not capture all perspectives, particularly from non-English speaking regions or non-academic sources. This limitation could potentially introduce bias in our findings towards certain viewpoints or technologies that are more prominently discussed in English-language academic literature.

Second, the generalizability of our findings across different industries or regions may be limited. The landscape of high-tech transfer can vary significantly depending on factors such as local regulations, economic conditions, and technological infrastructure. For instance, the challenges and opportunities identified in our study may be more applicable to developed economies with advanced technological infrastructures, and may not fully reflect the realities of emerging economies.

Third, our text mining approach, while powerful for analyzing large volumes of data, may miss nuanced or context-dependent information that could be captured through other methodologies such as case studies or interviews. For example, the complex dynamics of organizational culture and its impact on technology transfer might not be fully captured in published literature, and thus might be underrepresented in our analysis.

Despite these limitations, our study makes a significant contribution to the field by providing a data-driven, comprehensive overview of the key variables in high-tech transfer for Industry 5.0. The practical implications and actionable insights derived from our analysis can serve as a valuable resource for stakeholders navigating this complex landscape.

Considering these limitations, for future research in this field, it is recommended to conduct complementary qualitative studies such as in-depth interviews with experts and key stakeholders to gain more comprehensive and in-depth perspectives, expand the research to other languages and include sources and articles in various languages to increase data diversity, conduct case studies and examine the practical experiences of different companies, organizations, and countries and identify patterns and best practices, investigate the impact of specific factors such as cultural, political, and economic characteristics on this process, and monitor new developments and trends in high technologies and assess their impact on technology transfer. Conducting future research while considering these recommendations can provide a deeper and more comprehensive understanding of the phenomenon of international transfer of high technologies in Industry 5.0.

Furthermore, future research could focus on developing and testing the effectiveness of the actionable tools and frameworks proposed in this study, such as the Cross-disciplinary Collaboration Framework and the Sentiment-Based Technology Adoption Strategy. This could involve longitudinal studies to track the impact of these interventions on technology transfer success over time. Additionally, comparative studies across different industries and regions could help refine and adapt these tools to specific contexts, enhancing their practical applicability and impact.

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Appendix A. List of Analyzed Articles in Technology Transfer and Industry 5.0

Table A1. Articles Published in 2021 and Before.

No	Authors	Year	Title	Journal/Conference	DOI
1	Chen et al.	2021	A Human-Cyber-Physical System toward Intelligent Wind Turbine Operation and Maintenance	Sustainability	https://doi.org/10.3390/su13020561
2	Wang et al.	2021	BIM Information Integration Based VR Modeling in Digital Twins in Industry 5.0	Journal of Industrial Information Integration	https://doi.org/10.1016/j.jii.2022.100351
3	Hao et al.	2021	How does international technology spillover affect China's carbon emissions? A new perspective through intellectual property protection	Sustainable Production and Consumption	https://doi.org/10.1016/j.spc.2020.12.008
4	Skare & Soriano	2021	How globalization is changing digital technology adoption: An international perspective	Journal of Innovation & Knowledge	https://doi.org/10.1016/j.jik.2021.04.001
5	Fraga-Lamas et al.	2021	Green IoT and Edge AI as Key Technological Enablers for a Sustainable Digital Transition towards a Smart Circular Economy: An Industry 5.0 Use Case	Sensors	http://dx.doi.org/10.3390/s21175745
6	Aziz	2021	Promising Business Opportunities in the Industrial Age 4.0 and the Society Era 5.0 in the New-Normal Period of the Covid-19 Pandemic	Scholarly Journal of Psychology and Behavioral Sciences	https://doi.org/ 10.32474/SJPBS.2021.05.000216
7	ElFar et al.	2021	Prospects of Industry 5.0 in algae: Customization of production and new advance technology for clean bioenergy generation	Energy Conversion and Management: X	https://doi.org/10.1016/j.ecmx.2020.100048
8	Mancini & Calvo González	2021	Role of Technology Transfer, Innovation Strategy and Network: A Conceptual Model of Innovation Network to Facilitate the Internationalization Process of SMEs	Technology and Investment	https://doi.org/10.4236/ti.2021.122006
9	Narvaez Rojas et al.	2021	Society 5.0: A Japanese Concept for a Superintelligent Society	Sustainability	https://doi.org/10.3390/su13126567
10	Carayannis et al.	2021	Towards Fusion Energy in the Industry 5.0 and Society 5.0 Context: Call for a Global Commission for Urgent Action on Fusion Energy	Journal of the Knowledge Economy	https://doi.org/10.1007/s13132-020-00695-5
11	Alvarez-Aros & Bernal-Torres	2021	Technological competitiveness and emerging technologies in industry 4.0 and industry 5.0	Technological competitiveness and emerging technologies	https://doi.org/10.1590/0001-3765202120191290
12	Konno & Schillaci	2021	Intellectual capital in Society 5.0 by the lens of the knowledge creation theory	Journal of Intellectual Capital	https://doi.org/10.1108/JIC-02-2020-0060
13	Abrash	2021	Creating the future: Augmented reality, the next human-machine interface.	IEEE International Electron Devices Meeting (IEDM).	http://dx.doi.org/10.1109/IEDM19574.2021.9720526
14	Pereira et al.	2020	Industry 4.0 and Society 5.0: Opportunities and Threats	International Journal of Recent Technology and Engineering	https://doi.org/10.35940/ijrte.D8764.018520
15	Ellitan	2020	Competing in the Era of Industrial Revolution 4.0 and Society 5.0	Jurnal Maksipreneur: Manajemen, Koperasi, dan Entrepreneurship	http://dx.doi.org/10.30588/jmp.v10i1.657
16	Aslam et al.	2020	Innovation in the Era of IoT and Industry 5.0: Absolute Innovation Management (AIM) Framework	Information	https://doi.org/10.3390/info11020124
17	Foresti et al.	2020	Smart Society and Artificial Intelligence: Big Data Scheduling and the Global Standard Method Applied to Smart Maintenance	Engineering	https://doi.org/10.1016/j.eng.2019.11.014

18	Roblek et al.	2020	The Interaction between Internet, Sustainable Development, and Emergence of Society 5.0	Data	https://doi.org/10.3390/data5030080
19	Aquilani et al.	2020	The Role of Open Innovation and Value Co-creation in the Challenging Transition from Industry 4.0 to Society 5.0: Toward a Theoretical Framework	Sustainability	https://doi.org/10.3390/su12218943
20	Ferreira et al.	2020	Technology transfer, climate change mitigation, and environmental patent impact on sustainability and economic growth: A comparison of European countries.	Technological Forecasting and Social Change	https://doi.org/10.1016/j.techfore.2019.119770
21	Fukuda	2020	Science, technology and innovation ecosystem transformation toward society 5.0.	International journal of production economics	https://doi.org/10.1016/j.ijpe.2019.07.033
22	Martynov et al.	2019	Information Technology as the Basis for Transformation into a Digital Society and Industry 5.0	Quality Management, Transport and Information Security, Information Technologies	https://doi.org/10.1109/ITQMIS.2019.8928305.
23	Nahavandi	2019	Industry 5.0—A Human-Centric Solution	Sustainability	https://doi.org/10.3390/su11164371
24	Paschek et al.	2019	Industry 5.0 – The Expected Impact of Next Industrial Revolution	Management, Knowledge and Learning	

Table A2. Articles Published in 2022-2023.

No	Authors	Year	Title	Journal/Conference	DOI
1	Khan et al.	2023	Changes and improvements in Industry 5.0: A strategic approach to overcome the challenges of Industry 4.0	Green Technologies and Sustainability	https://doi.org/10.1016/j.grets.2023.100020
2	Hein-Pensel et al.	2023	Maturity assessment for Industry 5.0: A review of existing maturity models	Journal of Manufacturing Systems	https://doi.org/10.1016/j.jmsy.2022.12.009
3	Khan et al.	2023	Secure IoMT for Disease Prediction Empowered With Transfer Learning in Healthcare 5.0, the Concept and Case Study	IEEE Xplore	https://doi.org/10.1109/ACCESS.2023.3266156.
4	Al-qaness et al.	2023	Multi-ResAtt: Multilevel Residual Network With Attention for Human Activity Recognition Using Wearable Sensors	IEEE Transactions on Industrial Informatics	https://doi.org/10.1109/TII.2022.3165875
5	Ren et al.	2023	Technology transfer adoption to achieve a circular economy model under resource-based view: A high-tech firm.	International Journal of Production Economics	https://doi.org/10.1016/j.ijpe.2023.108983
6	Alam et al.	2023	Analysis of the drivers of Agriculture 4.0 implementation in the emerging economies: Implications towards sustainability and food security.	Green Technologies and Sustainability	http://dx.doi.org/10.1016/j.grets.2023.100021
7	Giugliano et al.	2023	Approaches and Technologies for the Human-Centered Industry 5.0.	Proyecta, an Industrial Design Journal	https://doi.org/10.25267/P56-IDJ.2023.i3.05
8	Humpert et al.	2023	Investigating the potential of artificial intelligence for the employee from the perspective of AI-experts	Technology Management, Operations and Decisions	http://dx.doi.org/10.1007/s44282-024-00051-x
9	Zhang et al.	2023	Towards new-generation human-centric smart manufacturing in Industry 5.0: A systematic review.	Advanced Engineering Informatics	http://dx.doi.org/10.1016/j.aei.2023.102121
10	Bocklisch & Huchler	2023	Humans and cyber-physical systems as teammates? Characteristics and applicability of the human-machine-teaming concept in intelligent manufacturing.	Frontiers in Artificial Intelligence	https://doi.org/10.3389/frai.2023.1247755
11	Brunzini et al.	2023	Human-centred data-driven redesign of simulation-based training: a qualitative study applied on two use cases of the healthcare and industrial domains.	Journal of Industrial Information Integration	https://doi.org/10.1016/j.jii.2023.100505
12	Carayannis et al.	2023	From the dark side of industry 4.0 to society 5.0: Looking "beyond the box" to developing human-centric innovation ecosystems.	IEEE Transactions on Engineering Management	https://doi.org/10.1109/tem.2023.3239552
13	Carayannis & Morawska	2023	University and education 5.0 for emerging trends, policies and practices in the concept of industry 5.0 and society 5.0. In: Industry 5.0: Creative and Innovative Organizations.	Cham: Springer International Publishing	http://dx.doi.org/10.1007/978-3-031-26232-6_1
14	Berretta et al.	2023	Defining human-AI teaming the human-centered way: A scoping review and network analysis	Frontiers in Artificial Intelligence	https://doi.org/10.3389/frai.2023.1250725
15	Ciccarelli et al.	2023	Exploring how new industrial paradigms affect the workforce: A literature review of Operator 4.0.	Journal of Manufacturing Systems	https://doi.org/10.1016/j.jmsy.2023.08.016
16	Rožanec et al.	2023	Human-centric artificial intelligence architecture for industry 5.0 applications	International Journal of Production Research	https://doi.org/10.1080/00207543.2022.2138611
17	Espina-Romero et al.	2023	Industry 5.0: Tracking Scientific Activity on the Most Influential Industries, Associated Topics, and Future Research Agenda	Sustainability	https://doi.org/10.3390/su15065554

No	Authors	Year	Title	Journal/Conference	DOI
18	R. Rajesh	2023	Industry 5.0: analyzing the challenges in implementation using grey influence analysis	Journal of Enterprise Information Management,	https://doi.org/10.1108/JEIM-03-2023-0121
19	Barata & Kayser	2023	Industry 5.0 – Past, Present, and Near Future	Procedia Computer Science	https://doi.org/10.1016/j.procs.2023.01.351
20	Santhi & Muthuswamy	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	https://doi.org/10.1007/s12008-023-01217-8
21	Coelho et al.	2023	Industry 5.0: The Arising of a Concept	Procedia Computer Science	https://doi.org/10.1016/j.procs.2022.12.312
22	Mourtzis et al.	2022	A Literature Review of the Challenges and Opportunities of the Transition from Industry 4.0 to Society 5.0	Energies	https:// doi.org/10.3390/en15176276
23	Alsamhi et al.	2022	Computing in the Sky: A Survey on Intelligent Ubiquitous Computing for UAV-Assisted 6G Networks and Industry 4.0/5.0	Drones	https:// doi.org/10.3390/drones6070177
24	Choi et al.	2022	Disruptive Technologies and Operations Management in the Industry 4.0 Era and Beyond	Production and Operations Management	https://doi.org/10.1111/poms.13622
25	Kolade & Owoseni	2022	Employment 5.0: The work of the future and the future of work	Technology in Society	ttps://doi.org/10.1016/j.techsoc.2022.102086
26	Sigov et al.	2022	Emerging Enabling Technologies for Industry 4.0 and Beyond	Information Systems Frontiers	https://doi.org/10.1007/s10796-021-10213-w
27	Yao et al.	2022	Enhancing wisdom manufacturing as industrial metaverse for industry and society 5.0	Journal of Intelligent Manufacturing	http://dx.doi.org/10.1007/s10845-022-02027-7
28	Zizic et al.	2022	From Industry 4.0 towards Industry 5.0: A Review and Analysis of Paradigm Shift for the People, Organization and Technology	Energies	https://doi.org/10.3390/en15145221
29	Adel	2022	Future of industry 5.0 in society: human-centric solutions, challenges and prospective research areas	Journal of Cloud Computing: Advances, Systems and Applications	https://doi.org/10.1186/s13677-022-00314-5
30	Zamany & Khamseh	2022	Identification of Influential Dimensions and Components of Technology Transfer with a focus on digital transformation	Journal of Technology Development Management	https://doi.org/10.22104/JTDM.2023.5698.3032
31	Saniuk et al.	2022	Identification of Social and Economic Expectations: Contextual Reasons for the Transformation Process of Industry 4.0 into the Industry 5.0 Concept	Sustainability	http://dx.doi.org/10.3390/su14031391
32	Ghobakhloo et al.	2022	Identifying industry 5.0 contributions to sustainable development: A strategy roadmap for delivering sustainability values	Sustainable Production and Consumption	https://doi.org/10.1016/j.spc.2022.08.003
33	Seyednaghavi et al.	2022	Human Resource Management Intelligence Pattern Based on Data Science and Machine Learning	Journal of Business Intelligence Management Studies	https://doi.org/10.22054/IMS.2022.66412.2169
34	Reddy Maddikunta et al.	2022	Industry 5.0: A survey on enabling technologies and potential applications	Journal of Industrial Information Integration	https://doi.org/10.1016/j.jii.2021.100257
35	Huang et al.	2022	Industry 5.0 and Society 5.0—Comparison, complementation and co-evolution	Journal of Manufacturing Systems	https://doi.org/10.1016/j.jmsy.2022.07.010
36	Leng et al.	2022	Industry 5.0: Prospect and retrospect	Journal of Manufacturing Systems	https://doi.org/10.1016/j.jmsy.2022.09.017
37	Iyengar et al.	2022	Industry 5.0 technology capabilities in Trauma and Orthopaedics	Journal of Orthopaedics	https://doi.org/10.1016/j.jor.2022.06.001
38	Borchardt et al.	2022	Industry 5.0 Beyond Technology: An Analysis Through the Lens of Business and Operations Management Literature	Organizacija,	https://doi.org/10.2478/orga-2022-0020
39	Kalygina	2022	International technology transfer as an effective tool of export-oriented import substitution in Russia	RUDN Journal of Economics	https://doi.org/10.22363/2313-2329-2022-30-2-231-241
40	Carayannis et al.	2022	Known Unknowns in an Era of Technological and Viral Disruptions—Implications for Theory, Policy, and Practice	Journal of the Knowledge Economy ():	https://doi.org/10.1007/s13132-020-00719-0
41	Jefroy et al.	2022	Moving from Industry 4.0 to Industry 5.0: What Are the Implications for Smart Logistics?	Logistics	https://doi.org/10.3390/logistics6020026
42	Carayannis et al.	2022	Smart Environments and Techno-centric and Human-Centric Innovations for Industry and Society 5.0: A Quintuple Helix Innovation System View Towards Smart, Sustainable, and Inclusive Solutions	Journal of the Knowledge Economy	https://doi.org/10.1007/s13132-021-00763-4
43	Kovaleski et al.	2022	The Challenges of Technology Transfer in the Industry 4.0 Era Regarding Anthropotechnological Aspects: A Systematic Review	SAGE Open	https://doi.org/10.1177/21582440221111104
44	Carayannis & Morawska	2022	The Futures of Europe: Society 5.0 and Industry 5.0 as Driving Forces of Future Universities	Journal of the Knowledge Economy	https://doi.org/10.1007/s13132-021-00854-2

No	Authors	Year	Title	Journal/Conference	DOI
45	Madhavan et al.	2022	The Precipitative Effects of Pandemic on Open Innovation of SMEs: A Scientometrics and Systematic Review of Industry 4.0 and Industry 5.0	Journal of Open Innovation: Technology, Market, and Complexity	https://doi.org/10.3390/joitmc8030152
46	Ayub Khan et al.	2022	Internet of Things (IoT) Security With Blockchain Technology: A State-of-the-Art Review	IEEE Access	https://doi.org/10.1109/ACCESS.2022.3223370
47	Shahzad et al.	2022	Investigating the spill overs and connectedness between financial globalization, high-tech industries and environmental footprints: Fresh evidence in context of China	Technological Forecasting and Social Change	https://doi.org/10.1016/j.techfore.2021.121205
48	Alkhazaleh et al.	2022	The Success of Technology Transfer in the Industry 4.0 Era: A Systematic Literature Review	Journal of Open Innovation: Technology, Market, and Complexity	https://doi.org/10.3390/joitmc8040202
49	Calp & Bütüner	2022	Society 5.0: Effective technology for a smart society. In: Artificial Intelligence and Industry 4.0.	Academic Press	http://dx.doi.org/10.1016/B978-0-323-88468-6.00006-1
50	Cunha et al.	2022	Exploring the status of the human operator in Industry 4.0: A systematic review	Frontiers in Psychology	https://doi.org/10.3389%2Ffpsyg.2022.889129
51	Lu et al.	2022	Outlook on human-centric manufacturing towards Industry 5.0	Journal of Manufacturing Systems	https://doi.org/10.1016/j.jmsy.2022.02.001
52	Cillo et al.	2022	Rethinking companies' culture through knowledge management lens during Industry 5.0 transition.	Journal of Knowledge Management	https://doi.org/10.1108/JKM-09-2021-0718

Table A3. Articles Published in 2024.

No	Authors	Year	Title	Journal/Conference	DOI
1	Navarro Zapata et al.	2024	Determinants of High-tech Exports: New Evidence from OECD Countries	Journal of the Knowledge Economy	https://doi.org/10.1007/s13132-023-01116-z
2	Baig & Yadegari dehkordi	2024	Industry 5.0 applications for sustainability: A systematic review and future research directions	Sustainable Development	https://doi.org/10.1002/sd.2699
3	Kumari et al.	2024	Infrastructure Potential and Human-Centric Strategies in the Context of Industry 5.0	Infrastructure Possibilities and Human-Centered Approaches With Industry 5.0	https://doi.org/10.1002/sd.2699
4	Abdel-Basset et al.	2024	Multi-Criteria Decision-Making Framework to Evaluate the Impact of Industry 5.0 Technologies: Case Study, Lessons Learned, Challenges and Future Directions.	Information Systems Frontiers	https://doi.org/10.1007/s10796-024-10472-3
5	Bissadu et al.	2024	Society 5.0 enabled agriculture: Drivers, enabling technologies, architectures, opportunities, and challenges	Information Processing in Agriculture	https://doi.org/10.1016/j.inpa.2024.04.003
6	Amin et al.	2024	The adoption of Industry 4.0 technologies by using the technology organizational environment framework: The mediating role to manufacturing performance in a developing country.	Business Strategy & Development	http://dx.doi.org/10.1002/bsd2.363
7	Leng et al.	2024	Unlocking the power of industrial artificial intelligence towards Industry 5.0: Insights, pathways, and challenges.	Journal of Manufacturing Systems	http://dx.doi.org/10.1016/j.jmsy.2024.02.010
8	Sojoodi & Baghbanpour	2024	The relationship between high-tech industries exports and GDP growth in the selected developing and developed countries.	Journal of the Knowledge Economy	http://dx.doi.org/10.1007/s13132-023-01174-3

آشکارسازی چشم‌انداز انتقال فناوری پیشرفته در صنعت ۵،۰: کاوشی مبتنی بر متن‌کاوی

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ارسال ۲۰۲۴/۰۵/۲۵ بازنگری ۲۰۲۴/۰۹/۰۱؛ پذیرش ۲۰۲۴/۱۱/۲۴

چکیده:

انتقال بین‌المللی فناوری‌های پیشرفته نقشی محوری در تحول صنایع و گذار به صنعت ۵،۰ ایفا می‌کند -پارادایمی که بر توسعه صنعتی انسان‌محور، پایدار و تاب‌آور تأکید دارد. با این حال، این فرآیند با چالش‌ها و پیچیدگی‌های متعددی مواجه است که مستلزم درک عمیق متغیرها و مفاهیم کلیدی آن می‌باشد. پژوهش حاضر با هدف شناسایی و تحلیل این متغیرها در حوزه انتقال فناوری پیشرفته در صنعت ۵،۰ انجام شده است. بر اساس پروتکل مرور نظام‌مند ادبیات، ۸۴ مقاله مرتبط منتشر شده بین سال‌های ۲۰۱۷ (زمانی که صنعت ۵،۰ برای نخستین بار به طور رسمی در نمایشگاه تجاری CeBIT معرفی شد) تا ۲۰۲۴ بر پایه معیارهای از پیش تعیین شده شامل ارتباط با موضوع تحقیق، کیفیت انتشار و تأثیر استنادی انتخاب شدند. این مقالات با استفاده از رویکرد متن‌کاوی شامل استخراج کلیدواژه‌ها، تحلیل احساسات، مدل‌سازی موضوعی و خوشه‌بندی مفاهیم که از طریق کتابخانه‌های پایتون از جمله NLTK، SpaCy، TextBlob و Scikit-learn پیاده‌سازی شده، مورد تحلیل قرار گرفتند. نتایج، متغیرها و مفاهیم کلیدی را در پنج خوشه اصلی دسته‌بندی می‌کند: فناوری‌های پیشرفته (شامل هوش مصنوعی، اینترنت اشیاء و رباتیک)، سازوکارهای انتقال فناوری، ویژگی‌های صنعت ۵،۰، چالش‌های پیاده‌سازی (مانند خطرات امنیت سایبری و هزینه‌های بالای پذیرش) و فرصت‌ها (شامل افزایش بهره‌وری و پتانسیل نوآوری)، و چارچوب‌های قانونی. این یافته‌ها جنبه‌های مختلف فرآیند انتقال فناوری را آشکار می‌سازند و بینش‌هایی را برای ذینفعان فراهم می‌کنند، درحالی‌که نقش حیاتی همکاری انسان و فناوری در صنعت ۵،۰ را برجسته می سازند. محدودیت‌های مطالعه شامل سوگیری احتمالی نا شی از تمرکز عمدتاً بر ادبیات انگلیسی زبان و محدودیت‌های ذاتی تحلیل متنی رایانشی در درک ظرافت‌های وابسته به زمینه است. این پژوهش به درک عمیق‌تر پویایی‌های انتقال فناوری در صنعت ۵،۰ کمک می‌کند و پیامدهای عملی برای سیاست‌گذاری و راهبردهای اجرایی ارائه می‌دهد.

کلمات کلیدی: انتقال فناوری، انتقال بین‌المللی، فناوری‌های پیشرفته، صنعت ۵،۰، متن‌کاوی.