IRSTI 28.23.02 https://doi.org/10.26577/jpcsit202548

Dinara Zhaisanova [1,*], Sholpan Jamanbalayeva [2], Diana Zhyilyssova [1], Ayaulym Baidulla [1]

[1] Al-Farabi Kazakh National University, Almaty, Kazakhstan
[2] The Institute of Philosophy, Political Science and Religious Studies of the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan, Almaty, Kazakhstan
*e-mail: Zhaisanova.Dinara@kaznu.kz

UNDERSTANDING DIGITAL TRANSFORMATION AND AGENTIC SYSTEM THROUGH BIBLIOMETRICS: DEVELOPING AN AGENTIC MODEL OF HUMAN–AI INTERACTION

Abstract. This study conducts a comprehensive bibliometric analysis of research on digital transformation within the social sciences from 1997 to 2024 and integrates these findings to develop an Agentic Model of Human–AI Interaction. Drawing on 389 articles indexed in the Web of Science database, the analysis examines publication dynamics, influential authors and institutions, citation structures, and thematic research clusters using RStudio-based bibliometric tools. Results reveal that digital transformation has evolved into a central driver of societal, economic, and cultural change, with research output peaking in 2021–2022. Prominent themes include artificial intelligence, innovation processes, digital media technologies, and the societal implications of emerging technologies. Beyond mapping the knowledge landscape, the study proposes a conceptual agentic system model that explains how AI agents process, interpret, and operationalize human queries through structured stages of planning, retrieval, reasoning, and response generation. This integration of bibliometric insights with system conceptualization contributes to a deeper understanding of the evolving human–AI relationship and highlights key gaps and future research opportunities in the study of agentic systems within digital transformation. Finally, by contextualizing the proposed architecture against existing paradigms, ReAct and AutoGPT, this research identifies critical design limitations in current autonomous frameworks and offers a structured, verification-centric alternative to guide future developments in reliable human-AI interaction.

Keywords: bibliometric analysis, digital transformation, social sciences, agentic system, human-AI interaction, conceptual structure.

1. Introduction

Digital transformation has become one of the most significant phenomena of modern times, exerting a profound impact on various aspects of society. It affects not only economic and technological domains but also cultural, social, and educational processes. Bibliometric analysis offers a unique opportunity to systematically explore the existing literature on this topic, identifying key trends, methodologies, and research directions.

Over the past few decades, digital transformation has emerged as one of the most influential forces reshaping modern society. As technological advancements such as artificial intelligence (AI), big data analytics, cloud computing, the Internet of Things (IoT), and blockchain increasingly permeate both private and public spheres, the concept of "digital transformation" has evolved from a strategic business imperative into a broader socio-technological phenomenon [1]. This transformation extends far beyond the digitization of services or the adoption of new technologies; it represents a fundamental reconfiguration of societal structures, cultural practices, economic models, and even individual behaviors. In light of its far-reaching consequences, understanding the multifaceted impact of digital transformation on society has become a critical area of inquiry across various academic disciplines [2].

Digital transformation can be broadly defined as the integration of digital technologies into all areas of human activity, leading to profound changes in how individuals interact, how organizations function, and how governments operate [3]. This integration not only optimizes existing processes but also digital transformation significantly improved corporate ESG performance [4]. In societal terms, digital transformation affects domains such as education, manufacturing, governance, labor markets, communication, and social inclusion. For instance, e-learning platforms have expanded access to education [5], digital technologies trigger changes in the

business process of manufacturing small and medium-sized enterprises [6], and digitalization have altered internalization theory's assumptions about the nature of firm-specific assets [7]. However, these transformations also bring about new challenges, including digital divides [8], data privacy concerns [9], algorithmic bias [10], and questions about the ethical governance of technology [11].

Given the wide-ranging effects of digital transformation, scholarly interest in its societal implications has grown exponentially. [12] identified the primary challenges associated with implementing digital transformation in public administration within the domains of education, science, and innovation, with particular emphasis on the absence of a clearly defined conceptual framework.

Despite this growing body of literature, the academic discourse remains fragmented, often constrained by disciplinary silos and methodological heterogeneity. As a result, it is challenging to gain a comprehensive and integrative understanding of the state of research on the societal impact of digital transformation.

In this context, bibliometric analysis offers a valuable methodological tool for systematically mapping the existing knowledge landscape. Bibliometric techniques enable researchers to quantify scholarly output, identify influential publications, authors, and institutions, and uncover emerging research trends and thematic clusters [13], [14]. By analyzing patterns in scientific literature, bibliometric studies provide an evidence-based overview of how a particular research field has evolved over time and where it may be headed. Such an approach is especially pertinent in dynamic, interdisciplinary domains like digital transformation, where conceptual boundaries are fluid and research agendas are continuously evolving.

The present study conducts a comprehensive bibliometric analysis of scholarly literature on the impact of digital transformation on society. Using data extracted from major scientific databases such as Web of Science, this study aims to trace the development of academic interest in this field, identify the most prolific authors and institutions, determine the most cited publications, and delineate key thematic areas and research frontiers. By doing so, the study seeks to answer the following research questions:

1. How has the scientific output on the societal impacts of digital transformation evolved over time, and what temporal patterns can be observed in publication dynamics?
2. What major thematic areas, conceptual clusters, and knowledge domains have emerged in this field, and how do they reflect the shifting research focus over time?
3. What research gaps and future directions can be identified based on the existing bibliometric landscape, particularly in relation to the integration of advanced AI technologies?
4. How do the identified bibliometric patterns, thematic clusters, and research gaps contribute to the formulation of an Agentic Model of Human–AI Interaction, and what insights does this model provide for understanding the evolving role of AI in digital transformation processes?

This study made several contributions to the literature. Firstly, it offers a panoramic view of academic research on digital transformation's societal implications, thus serving as a foundational reference for scholars new to the field. Secondly, by identifying influential works and research networks, it facilitates scholarly engagement and collaboration across disciplines and geographies. Thirdly, it was provided policymakers and practitioners with insights into the evolution of digital transformation discourse, which may inform evidence-based decision-making in areas such as digital governance, regulation, and social innovation.

The rest of the paper is organized as follows: The next section reviews the conceptual background of digital transformation and its societal relevance, followed by a discussion of the methodological framework employed for bibliometric analysis. The results section presents the main findings, including performance indicators and thematic mappings. This is followed by a discussion of key insights and their implications. Finally, the paper concludes with a summary of contributions, limitations, and suggestions for future research.

By conducting a rigorous bibliometric analysis, this study seeked not only to chart the intellectual contours of a rapidly evolving field but also to foster a more integrative and interdisciplinary understanding of how digital transformation is shaping contemporary society. In an era increasingly defined by technological acceleration and socio-digital convergence, such insights are vital for navigating the complexities and opportunities of our digitally mediated world.

In recent decades, digital transformation has emerged as a defining factor in reshaping the structure and dynamics of contemporary society. This process influences various spheres of life, including the economy, education, culture, and social rela-

tions. Digitalization provides new tools and platforms that transform interactions among individuals, organizations, and governmental institutions. Consequently, there is a growing need for a systematic analysis of the impact of digital transformation on society, necessitating the application of modern research methodologies. Bibliometric analysis, which relies on the quantitative study of scientific literature, has become a crucial tool in understanding how and to what extent digital transformation affects the social sciences.

In conclusion, the bibliometric analysis conducted in this study represents a crucial step toward a deeper understanding of digital transformation's influence on social processes. It provides researchers, policymakers, and practitioners with valuable data and analytical tools necessary for responding effectively to the challenges posed by digitalization and for developing strategic management approaches in an increasingly dynamic digital environment.

Literature review

Digital transformation has a significant impact on various aspects of society, including cultural heritage, governance, and economic development. Several studies examine key elements of this process through the lens of bibliometric analysis, allowing for the identification of major trends and research directions in the field.

Chen et al. explore the relationship between intangible cultural heritage and experiential marketing strategies in the context of digitalization in China. Their bibliometric analysis, conducted using CiteSpace, reveals that integrating intangible cultural heritage with digital products, such as games, contributes to its preservation and dissemination. This opens new avenues for future innovations in experiential marketing and underscores the importance of leveraging digital technologies to support cultural heritage [15].

Maulana and Decman provided a review of academic research on collaborative governance and digital transformation, emphasizing the emerging topic of Collaborative Digital Transformation (CDT). Their bibliometric analysis highlights the need for further research in this evolving field, which is currently establishing its unique identity in academic literature [16].

The challenge of defining clear boundaries for digital transformation research is attributed to the diversity of terminology and the broad scope of the subject. Van Veldhoven, Z.; Etikala, V.; Goossens, A.; and Vanthienen, J. employ bibliometric analysis using VOSviewer to identify the knowledge structure within this field. Their study underscores the necessity for further exploration of digital transformation's societal impact and the need to systematize existing knowledge [17].

Roblek et. al examined key technological innovations driving the transition from Society 4.0 and Industry 4.0 to Society 5.0 and Industry 5.0. By conducting a quantitative bibliometric analysis of 36 articles from the Web of Science database, they identify artificial intelligence, cyber-physical systems, and big data as central concepts in the research agenda. This highlights the necessity of integrating these technologies to adapt services and production processes to the real needs of society [18].

Furthermore, the study by Stoica et. Al. analyzed the impact of technological advancements on economic and social development, focusing on the growth of FinTech. The authors use bibliometric analysis to examine the link between FinTech adoption and education, emphasizing that education is a key factor for the successful implementation of financial technologies [19].

Thus, bibliometric analysis serves as a powerful tool for investigating the impact of digital transformation on society [20], enabling the identification of key trends, challenges, and future research directions.

2. Materials and Methods

This paper presents a bibliometric study conducted using the RStudio tool and the Biblioshiny library. The research is based on articles from the Web of Science database that include the key terms "digital transformation" and "social sciences." At the second stage, it was applied search including keywords "Agentic system for human–AI interactions" from the Web of Science database with analysis of 33 publications. The primary objective of this study is to analyze the literature to demonstrate how digital transformation influences society and to identify the main directions, trends, and interconnections in this field.

The study consists of five main stages:

1. Defining Search Criteria – At the initial stage, the primary search criteria were formulated, taking into account key terms, publication types, and timeframes. This approach allowed the focus to remain on the most relevant studies that would be further analyzed.

2. Selection of the Web of Science Database – The Web of Science database was chosen as

the primary data source due to its authoritative status as a leading platform for scientific publications. Its extensive coverage and high-quality content ensure the reliability and relevance of the retrieved data.

3. Refinement of Research Criteria – At this stage, the initially established criteria were thoroughly reviewed and refined. This process included filtering by publication timeframe, types of publications, and citation levels, ensuring greater precision and relevance in the analysis.

4. Exporting Final Data – After completing the search and refinement steps, the final dataset was collected and exported for further analysis. This process was automated, significantly simplifying subsequent data processing and evaluation.

5. Analysis and Discussion of Results – In the final stage, a comprehensive analysis of the obtained data was conducted using various bibliometric methods, including Annual Scientific Production, Production Trend Analysis, Three-field Plot, Average Citation per Year, as well as an examination of the most relevant sources, countries, authors, and the creation of a word cloud. These methods not only provided quantitative insights but also facilitated data visualization, enhancing the interpretation of results.

The application of bibliometric analysis methods enables the identification of key trends in scientific literature regarding the impact of digital transformation on society. Annual Scientific Production and Production Trend Analysis help assess the dynamics of publication activity in this field, while Three-field Plot and Average Citation per Year facilitate the examination of the most influential sources and authors. Data visualization through Word Cloud and thematic maps effectively illustrates core concepts and research directions.

Furthermore, the VOSviewer library provides powerful tools for constructing relational networks between authors, publications, and keywords, significantly enriching the analysis and revealing hidden interconnections. Consequently, the findings of this study not only confirm the substantial impact of digital transformation on various aspects of society but also highlight new avenues for future research in the social sciences. This analysis enhances our understanding of how digital transformation is reshaping society, identifying emerging challenges and opportunities for further development.

2.1. Data organisation and sampling

This study relies exclusively on the Web of Science database, as synchronizing bibliometric data obtained from multiple sources is challenging and can reduce the reliability of the bibliometric analysis. Web of Science is the preferred tool for assessing research outcomes due to its integrated interface and comprehensive coverage. Moreover, the use of a single database for bibliometric analysis is a widely accepted and standard practice. Web of Science also includes research in the social sciences, covering key publications in this field.

Table 1 – Document selection criteria from Web of Science

№	Search Stages	Number of Records
1	All documents containing the terms “Digital Transformation” and “Social Sciences” in the title, abstract, and keywords	389
2	Period from 1997 to 2007	17
3	Period from 2008 to 2017	32
4	Period from 2018 to 2024	340

The search strategy used to collect relevant data was as follows: Topic: “Digital Transformation” and “Social Sciences”. A total of 389 documents containing these terms in their titles, abstracts, and keywords were identified (Table 1). The analysis was conducted across three time periods:

• 1997–2007: 17 records were found.

• 2008–2017: The number of publications increased to 32.

• 2018–2024: A significant surge in interest was observed, with 340 publications identified in this period.

This trend demonstrates a sharp increase in research on digital transformation in the social sciences in recent years.

2.2. Research Design

The research objective was successfully achieved using VOSviewer and the R package with

the biblioshiny module. VOSviewer allows for the creation of country maps based on co-authorship networks, keyword maps linked by network structures, and various other visualizations. Additionally, the software is employed for data analysis, visualization, and clustering of articles extracted from databases. Meanwhile, the R package serves as a comprehensive tool for statistical processing and data visualization, further enhancing the bibliometric analysis.

2.3. Bibliometric analysis

To assess the quality and trends of publications over a specific period, a bibliometric method was applied, based on the analysis of a large volume of peer-reviewed works. This method enables researchers to efficiently process vast amounts of documents and extract key insights using scientific identification, statistical data, and systematic literature review.

It is important to note that bibliometrics includes co-authorship analysis and co-occurrence analysis as its core components. The application of bibliometric analysis also aids in statistically describing various research domains, which are illustrated in Figure 1.

The units of analysis and their subcomponents, which describe the course of the study, are presented and described in Table 2 below.

Figure 1 – The flowchart depicting the methodology for Bibliometric Research

Table 2 – Analysis unit and Sub-Components

Analysis Unit	Sub-Components
Dataset	Annual Scientific Production Average Citations per Year Three-field Diagram Most Significant Sources
Sources	CiteScore of Publications per Year
Authors	Most Significant Authors
Country	Analysis of Scientific Production and Citations by Country Countries of Corresponding Authors
Document	Most Cited Articles Worldwide Documents by Subject Areas and Types Word Cloud
Conceptual Structure	Thematic map Factor Analysis
Intellectual Structure	Co-authorship Network

3. Results and Discussions

3.1 Three-field plot

Figure 2 presents a three-field plot (Sankey diagram) that visualizes the relationship between journals (left column), authors (middle column), and keywords (right column) associated with digital transformation in the social sciences. The diagram highlights which journals focus more heavily on specific topics, as identified through author-selected keywords.

The width of the rectangles and connecting flows is proportional to the number of publications, indicating the strength of associations between the elements. Notably, the keywords “digital transformation” and “COVID-19” are associated with the thickest flows, suggesting they are among the most frequently used terms across multiple journals and authors.

Furthermore, journals such as Omics: A Journal of Integrative Biology and Pattern Recognition exhibit a broader range of keyword usage compared to other sources. This indicates that these journals tend to publish articles that address a wider array of topics, including those related to quality assurance and interdisciplinary approaches within the context of digital transformation.

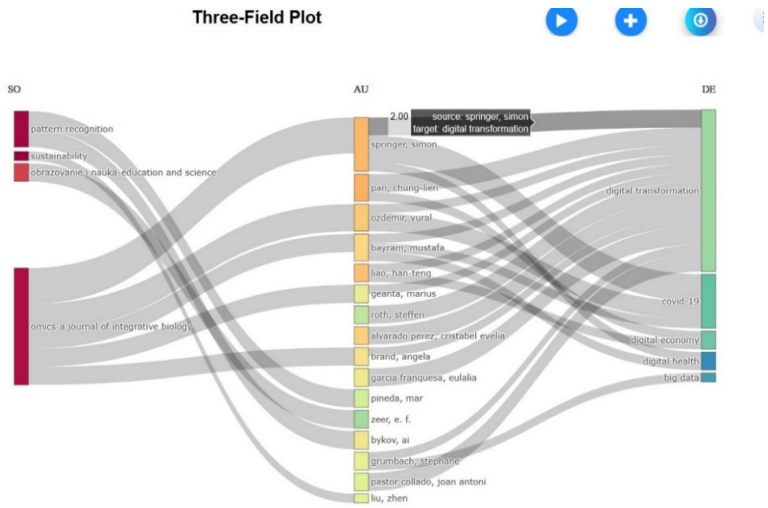

Figure 2 – Source – Authors – Keywords

3.2. Sources

3.2.1. Most relevant sources

Table 3 above displays the 10 most significant sources in this field. The journal with the highest number of publications (13) in this area is the journal "SUSTAINABILITY."

Table 3 – Most Relevant Sources

Sources	Articles
SUSTAINABILITY	13
PATTERN RECOGNITION	10
OMICS-A JOURNAL OF INTEGRATIVE BIOLOGY	9
JOURNAL OF IMAGING SCIENCE AND TECHNOLOGY	7
AMAZONIA INVESTIGA	4
INFORMATION TECHNOLOGIES AND LEARNING TOOLS	4
NAUCHNYE I TEKHNICHESKIE BIBLIOTEKI-SCIENTIFIC AND TECHNICAL LIBRARIES	4
OBRAZOVANIE I NAUKA-EDUCATION AND SCIENCE	4
TOMSK STATE UNIVERSITY JOURNAL	4

3.3. Authors

3.3.1. Most relevant authors

Although literature on digital transformation in social sciences is not as extensive as in otherareas of education, Figure 3 below shows that Pang Chung-Lien and Simon Springer rank first in the list with 4 relevant articles, i.e., the contribution of one author to the published set of articles. Their research focuses on several critical areas related to the emergence of a new scientific field: digital transformation research (DTR), which is characterized by significant complexity and diversity of research objects, making it difficult to analyze within individual disciplines.

The study shows that the concept of interdisciplinarity in DTR is mainly perceived as multidisciplinarity, with most participants in the discussions noting that they face more challenges than opportunities in the context of the interdisciplinary approach.

Table 4 shows the countries of the corresponding authors. In this context, two types of publications are highlighted: single-country publications (SCP), where all authors are from one country, representing internal collaboration, and multi-country publications (MCP), where all authors are from different countries, representing international collabo-

ration. The MCP ratios presented in Table 4 show that the two most productive countries occupy low positions. Moreover, the most productive countries, such as Russia and China, with low MCP ratios, do not rank highly in citations per article, meaning their citation rate per article does not make it into the top three countries. This situation can be described as a finding that highlights the importance of international collaboration to increase citations per publication.

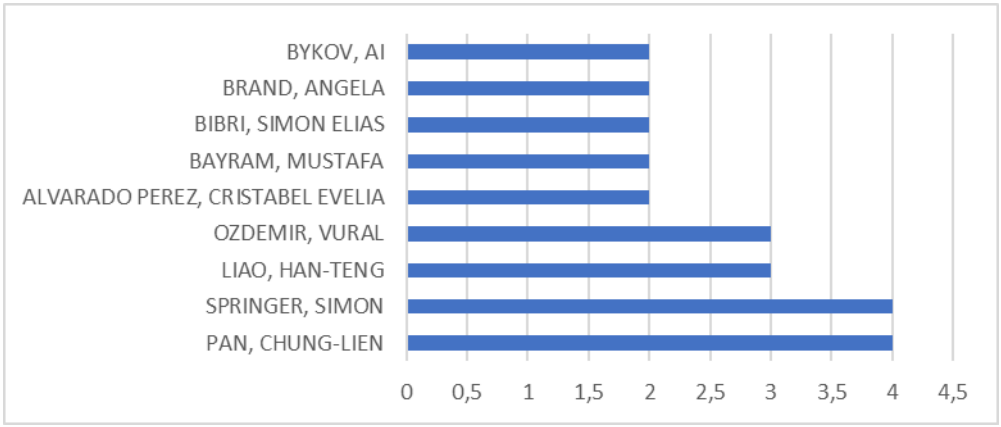

Figure 3 – Most prominent authors

Table 4 – Most Relevant Countries by Citation Analysis

Country	Articles	Articles %	SCP	MCP	MCP %
Russia	65	16,7	64	1	1,5
China	28	7,2	21	7	25
Germany	26	6,7	20	6	23,1
Ukraine	25	6,4	24	1	4
USA	22	5,7	17	5	22,7
Spain	21	5,4	19	2	9,5
Italy	16	4,1	11	5	31,3
Brazil	10	2,6	8	2	20
France	10	2,6	4	6	60
United Kingdom	10	2,6	5	5	50

Figure 4 presents a comprehensive bibliometric analysis combining two indicators: the annual number of publications and the average number of citations per year in the field of digital transformation in the social sciences over the period from 1997 to 2023. From 1997 to 2016, the number of publications remained relatively stable. However, starting in 2017, the field began to experience growing academic interest, as evidenced by a marked increase in the number of published articles. The peak in publication activity occurred in 2022, with 78 articles, followed by 2021 with 65 publications. In parallel, the graph illustrates the dynamics of citation impact, with the highest average number of citations per article recorded in 2023, reaching 8.2. This dual analysis highlights both the quantitative growth and the increasing scholarly influence of research on digital transformation within the social sciences.

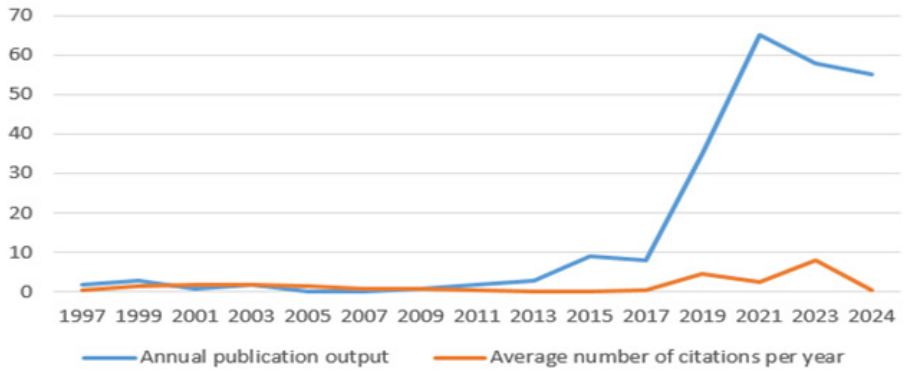

Figure 4 – Annual Trends in Publication Volume and Average Citations in the Field of Digital Transformation in Social Sciences (1997–2024)

3.4. Documents

3.4.1. Most globally cited articles

The list of the most cited documents in the field of digital transformation in social sciences is presented in Table 5. Figures 5 and 6 provide a graphical representation of citations by authors and bibliographic connections of documents.

Below are the details of some of the most significant cited documents:

Sachs, JD; Schmidt-Traub, G; Mazzucato, M; Messner, D; Nakicenovic, N; Rockström, J (2019) – Six Transformations to achieve the Sustainable Development Goals, Nature Sustainability: This study addresses the importance of interdisciplinarity in digital transformation research, identifying the challenges and opportunities faced by scholars from various disciplines. It also emphasizes the significance of international cooperation for enhancing publication citations.

Dwivedi, Yogesh K.; Kshetri, Nir; Hughes, Laurie; Slade, Emma Louise; Jeyaraj, Anand; Kar, Arpan Kumar; Baabdullah, Abdullah M.; Koohang, Alex; Raghavan, Vishnupriya; Ahuja, Manju; Albanna, Hanaa (2023) – So what if ChatGPT wrote it? Multidisciplinary perspectives on opportunities, challenges, and implications of generative conversational AI for research, practice, and policy, International Journal Of Information Management: This paper explores the transformative opportunities and challenges associated with the use of tools like ChatGPT in various fields. It highlights their potential for boosting productivity, as well as the ethical and legal aspects that require further investigation in the context of knowledge, transparency, and the digital transformation of organizations and societies.

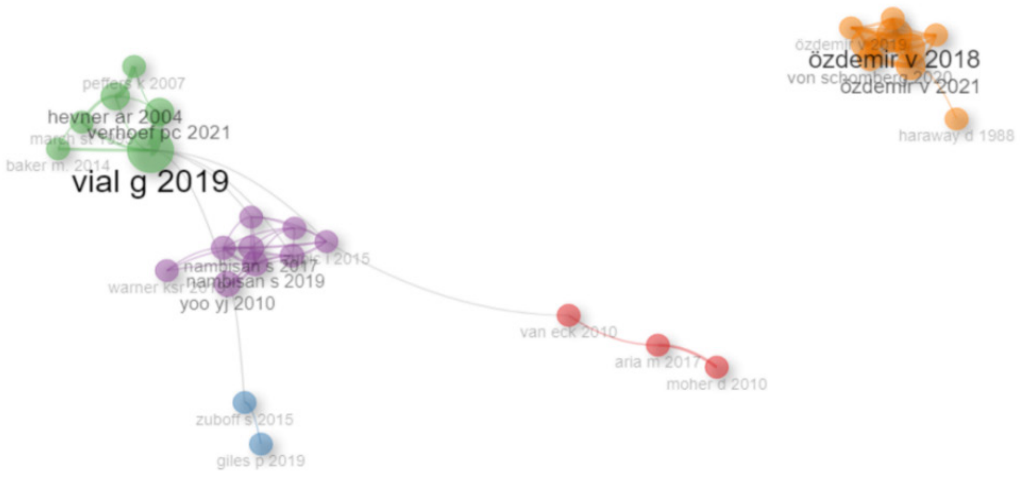

Figure 5 – Citation by authors

Castro, Gema Del Rio; Fernandez, Maria Camino Gonzalez; Colsa, Angel Uruburu (2021) – Unleashing the convergence amid digitalization and sustainability towards pursuing the Sustainable Development Goals (SDGs): A holistic review, JOURNAL OF CLEANER PRODUCTION: This article investigates the relationship between the Sustainable Development Goals (SDGs) and digitalization within the framework of the UN 2030 Agenda. It identifies research gaps and opportunities related to the use of digital paradigms, such as big data and artificial intelligence, to overcome sustainable development challenges and foster a more sustainable society.

Table 5 – Most Globally Cited Articles

Paper	DOI	Total Citations	TC per Year	Normalized TC
SACHS JD, 2019, NAT SUSTAIN	10.1038/s41893-019-0352-9	894	149,00	27,07
DWIVEDI YK, 2023, INT J INFORM MANAGE	10.1016/j.ijinfomgt.2023.102642	806	403,00	48,26
CASTRO GD, 2021, J CLEAN PROD	10.1016/j.jclepro.2020.122204	230	57,50	20,23
DIMIDUK DM, 2018, INTEGR MATER MANUF I	10.1007/s40192-018-0117-8	186	26,57	6,49
ALHAWARI O, 2021, SUSTAINABILITY-BASEL	10.3390/su13020859	128	32,00	11,26
KESKIN H, 2018, GEODERMA	10.1016/j.geoderma.2018.04.004	113	16,14	3,94
GUO HD, 2020, INT J DIGIT EARTH	10.1080/17538947.2020.1743785	72	14,40	7,92
COZZOLINO D, 2003, LEBENSM-WISS TECHNOL	10.1016/S0023-6438(02)00199-8	69	3,14	1,77
DUMONT B, 2018, ANIMAL	10.1017/S1751731118001350	69	9,86	2,41

The analysis of Co-occurrence Network by author keywords is also presented in Figure 6. This analysis was conducted in the R-based tool bibliometrix. The figure presents a keyword co-occurrence network illustrating the conceptual structure of research related to digital transformation and artificial intelligence within the social sciences. The visualization is generated using VOSviewer and displays clusters of frequently co-occurring terms. Node size reflects the relative frequency of keyword occurrence, while the thickness of connecting lines indicates the strength of co-occurrence relationships.

At the center of the network are two dominant terms–"agentic AI" and "artificial intelligence" – which form the core of the research landscape and demonstrate strong interconnections with multiple thematic clusters. The red cluster, anchored by agentic AI, encompasses themes such as digital twins, industry 5.0, human-in-the-loop, and multi-agent systems, highlighting technological and organizational dimensions of digital transformation. The blue cluster centers on cognition, real-time systems, urban areas, and complexity theory, indicating interdisciplinary applications of AI in socio-technical environments.

The green cluster groups keywords related to computational advancements, including machine learning, models, and Large Language Models (LLM), emphasizing methodological foundations. A smaller purple cluster links open systems theory, AI adoption, and digital intelligence, reflecting conceptual frameworks used to interpret the societal impact of AI-driven transformation.

Overall, the figure demonstrates the multi-clustered and interconnected nature of the research domain, revealing how artificial intelligence serves as a central integrating concept across technological, methodological, cognitive, and theoretical dimensions of digital transformation studies.

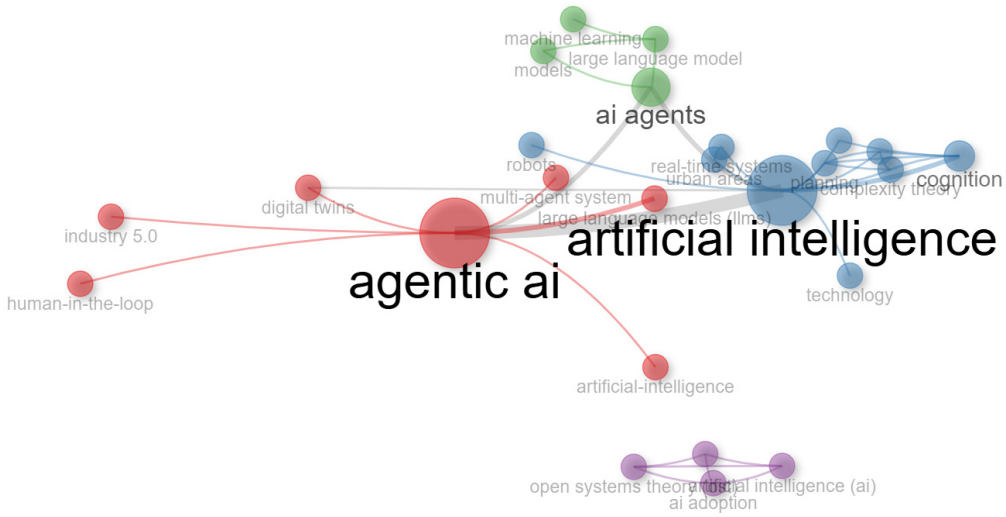

Figure 6 – Co-occurrence Network (author keywords)

3.5. Conceptual Structure

3.5.1. Thematic map

The thematic map presented in Figure 7 generated through a co-word analysis of the literature related to agentic systems and human–AI interactions. The map positions themes across two dimensions: relevance (centrality) on the horizontal axis and development (density) on the vertical axis. The resulting quadrants classify themes as motor, niche, emerging/declining, or basic, thereby offering insight into the intellectual structure and maturity of research in this domain.The analysis reveals the intricate structure of academic discourse on digital transformation and its far-reaching implications for various sectors of society.

Motor Themes: Highly Developed and Central

Clusters located in the upper-right quadrant represent mature and influential research themes. The largest and most prominent cluster, encompassing terms such as “artificial intelligence,” “cognition,” and “complexity theory,” indicates that conceptual and cognitive foundations of AI form a core area of scholarship. This suggests a research field anchored in theories of intelligent behavior, adaptive systems, and computational modeling.

Adjacent to this cluster is another substantial motor theme centered on “agentic AI,” “large language models,” and “chatGPT.” Its size and centrality reflect the rapid expansion of research focusing on autonomous AI systems, generative models, and the challenges associated with designing systems capable of agentic behavior. Together, these motor themes illustrate that contemporary inquiry is strongly oriented toward technically sophisticated and conceptually fundamental issues in AI agency.

Basic Themes: Central but Underdeveloped

The lower-right quadrant contains themes with high relevance but comparatively lower density, indicating foundational areas that remain theoretically or methodologically underdeveloped. Terms such as “artificial-intelligence technology,” “generative AI,” and “agentic system” appear here, suggesting that although these topics are central to current discourse, they require further conceptual clarification and empirical work. The positioning of “agentic system” specifically highlights its emerging significance as a conceptual anchor for research on autonomous AI behavior and human–AI interaction frameworks.

Niche Themes: Well-Developed but Peripheral

In the upper-left quadrant, clusters including “AI adoption,” “open systems theory (OST),” and “artificial intelligence (AI)” represent niche yet technically advanced areas. Their high density indicates well-established internal coherence, while their limited centrality suggests application in specialized subfields–such as organizational AI adoption modeling or systems-theoretic interpretations of AI integration. These themes contribute depth to the field but are not yet structurally central to the broader research landscape on agentic AI.

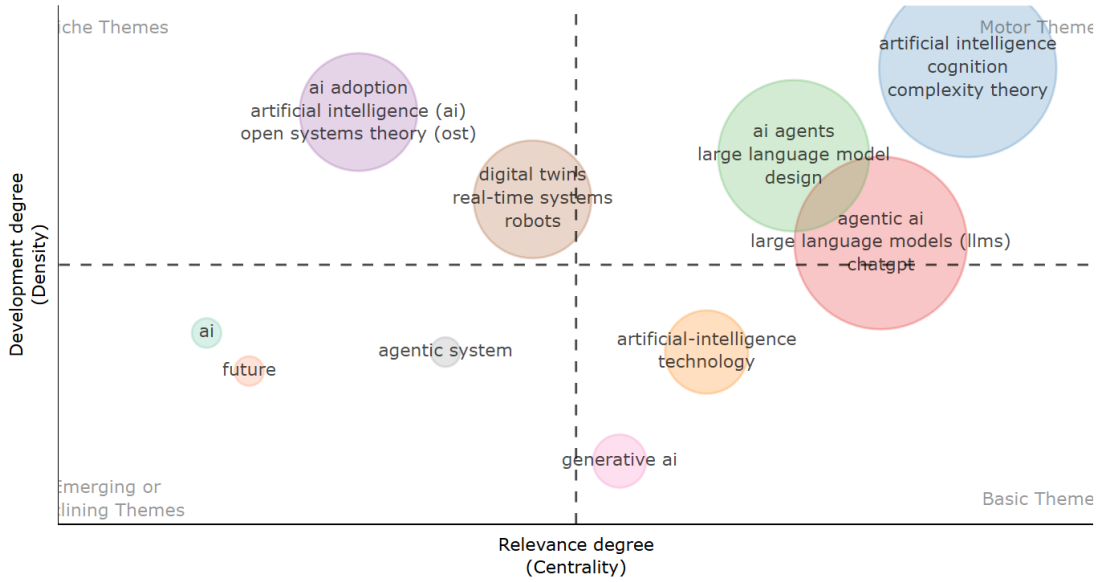

Figure 7 – Thematic Map (Authors' Keyword)

Another niche cluster – involving "digital twins," "real-time systems," and "robots"–illustrates specialized applications of agentic or semi-autonomous AI within engineering, robotics, and cyber-physical systems. Although methodologically robust, these themes remain somewhat peripheral to the conceptual and psychological questions driving human–AI interaction research.

Emerging or Declining Themes

The lower-left quadrant includes less-developed and less-central topics such as "AI," "future," and "generative AI." Their position may indicate either nascent lines of inquiry or areas where scholarly attention is currently limited or shifting. The dispersed nature of the cluster underscores ongoing conceptual expansion and suggests that these topics may evolve into more defined themes as research on agentic and autonomous AI progresses.

In conclusion, the thematic map offers a structured overview of the contemporary research landscape surrounding agentic systems and human–AI interactions. The map identifies the core themes that currently shape theoretical and technological development–most notably the clusters related to artificial intelligence, cognition, complexity theory, and agentic AI–highlighting their central role in advancing the field. At the same time, it reveals specialized and technically mature niches, such as AI adoption, open systems theory, digital twins, and real-time robotic systems, which contribute depth while remaining peripheral to the broader conceptual discourse.

The map also points to foundational yet still developing areas, including generative AI, artificial-intelligence technologies, and emerging conceptualizations of agentic systems. These themes are poised to guide future research as scholars continue to refine definitions, methodological approaches, and design principles for autonomous and semi-autonomous AI agents.

As the research domain evolves, it will be essential to deepen theoretical and empirical understanding of how agentic AI systems can be aligned with human cognitive, social, and ethical expectations. The ongoing development of these themes will provide crucial insights into the design of adaptive, reliable, and culturally responsive systems capable of supporting advanced forms of human–AI collaboration.

3.5.2. Factorial analysis

A multiple correspondence analysis (MCA) was conducted on the set of author keywords to examine the conceptual structure underlying contemporary research relevant to the development of agentic systems for human–AI interactions. By applying dimensionality-reduction techniques, the analysis identifies latent associations among key terms and reveals the dominant thematic directions shaping the field.

Figure 8 displays the resulting conceptual map. Unlike earlier domain configurations centred on digital transformation, the present analysis indicates

that research on agentic human–AI systems is organised around clusters of high-centrality concepts associated primarily with large language models (LLMs), AI ethics, multi-agent systems, and artificial intelligence. These terms occupy the dense central region of the map, confirming their constitutive role in structuring theoretical and empirical advancements in human–AI interaction.

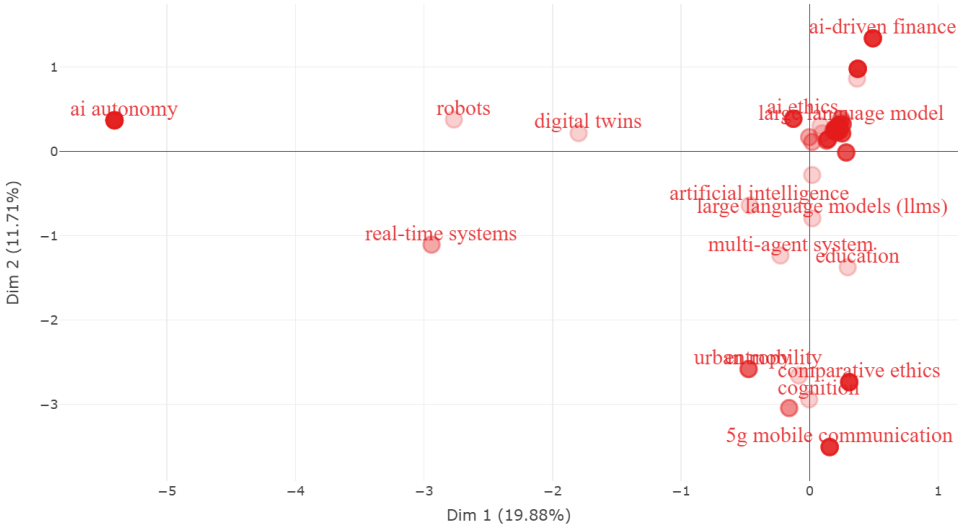

Figure 8 – Conceptual Structure Map

Further, the map highlights a set of application-oriented themes, including AI-driven finance, education, and technology design, which are positioned near the central cluster but extend along the first dimension. Their proximity suggests strong conceptual dependencies between foundational AI capabilities and sector-specific implementations, particularly in domains where agentic AI systems mediate or automate complex decision processes.

In contrast, terms such as robots, digital twins, real-time systems, and AI autonomy are distributed across the left-hand side of the map. Their relative distance from the central cluster indicates specialised but less integrative research areas, often oriented toward engineering, systems design, and autonomy modelling rather than social or cognitive dimensions of human–AI engagement.

Peripheral concepts located in the lower regions–such as urban mobility, comparative ethics, cognition, and 5G mobile communication–reflect emerging interdisciplinary directions. While these terms exhibit lower centrality, they represent expanding interfaces where agentic AI systems intersect with infrastructural, ethical, and cognitive frameworks, suggesting promising pathways for future inquiry.

Collectively, the MCA reveals a conceptual architecture dominated by the convergence of LLMs, ethical frameworks, and multi-agent system design, while simultaneously highlighting adjacent technological and interdisciplinary domains. These findings underscore the growing importance of agentic, adaptive, and ethically aligned AI systems, reinforcing the need for integrative models that capture both the cognitive mechanisms and the societal implications of human–AI interactions.

These findings highlight the growing importance of agentic, adaptive, and ethically aligned AI, and they reinforce the need for integrative models that explain both the cognitive mechanisms of agents and the societal implications of human–AI interaction in digitally transforming organizations. In other words, bibliometrics does more than map trends; it helps identify which capabilities and governance requirements must be addressed together when AI moves from laboratory prototypes to operational services.

To move from this bibliometric landscape to an implementable system, an operational definition of agency is required. An artificial intelligence agent is defined not simply by information processing, but by the capacity for autonomous action. In classical

agent architectures, an intelligent system integrates perception, internal deliberation, and memory to select actions that advance a goal. This perspective, summarized in Fig. 9 [21], is directly relevant to digital transformation because it frames AI as an active component within workflows, data platforms, and decision processes, where reliability, traceability, and accountability are necessary properties.

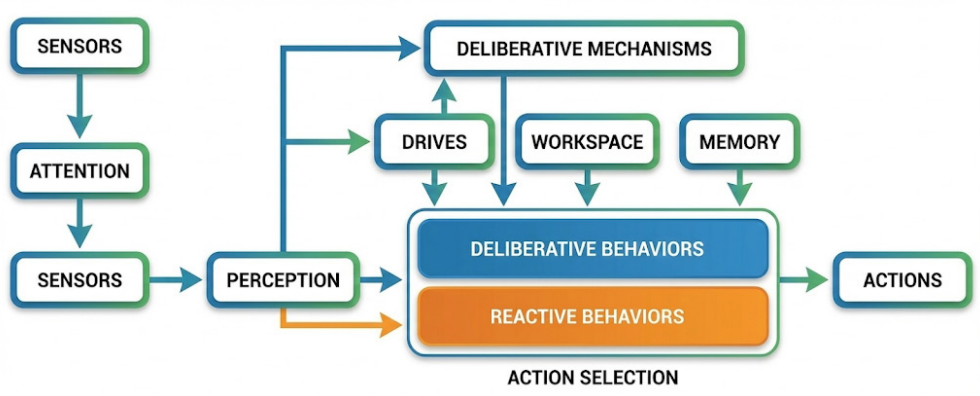

Figure 9 – Schematic Representation of an Autonomous Agent's Action Selection Mechanism

Recent progress in large language models provides a practical mechanism to instantiate this classical blueprint. As benchmark performance continues to improve [22], LLMs increasingly support capabilities that are central to human–AI interaction, including intent recognition, summarization, content generation, and multi-step reasoning. As a result, contemporary agentic systems often implement deliberation by treating the LLM as a cognitive engine and implement action through tool use. In this setting, retrieval systems and external databases provide grounded "memory," APIs and computational tools serve as executable "actions," and structured control logic determines when to search, when to verify, and when to respond. Framed through the lens of digital transformation, this architecture offers a concrete pathway from bibliometric themes to deployable systems because it links human intent to machine action through evidence access, verifiable decision points, and auditable workflows.

To operationalize the theoretical definition of agency, recent work has converged on a small number of recurring architectural patterns. Two influential exemplars, Auto-GPT [23] and ReAct [24], illustrate contrasting paradigms that continue to shape how agentic AI systems are designed and evaluated.

ReAct (Reasoning and Acting) couples internal reasoning with tool-mediated interaction by interleaving thought steps and action steps. The central idea is that an agent should not rely on free-form reasoning alone. Instead, it should repeatedly consult external resources, observe the outcome, and update its reasoning accordingly. This grounding mechanism mitigates error propagation typical of purely chain-of-thought prompting, because the model can retrieve missing facts, check assumptions against evidence, and adapt its plan as new observations arrive. In practice, ReAct is lightweight and effective for tool-augmented question answering, but its reliability depends on whether the model can recognize when evidence is sufficient and when it must continue searching or revising.

Auto-GPT represents a different design goal, long-horizon autonomy for open-ended objectives. Rather than a single reasoning-action loop, Auto-GPT maintains a persistent task structure in which a high-level goal is decomposed into sub-tasks, executed iteratively, and reprioritized as intermediate outcomes arrive. Its contribution is the operationalization of continuous self-prompting and memory, enabling an agent to sustain progress without constant human steering. This paradigm is well suited to exploratory tasks and multi-step project execution, but it can incur high computational cost and may drift into irrelevant branches when objectives are underspecified or when constraints are not explicitly enforced.

Although both paradigms have advanced the field, their limitations become salient in precision-critical, retrieval-centered settings. ReAct can produce confident hallucinations when it treats tool outputs as correct without explicit checking, and it can also fall into reasoning loops where it keeps searching despite already having adequate evidence. Auto-

GPT's recursive structure may amplify these issues at scale. It is prone to rabbit holes, repeated sub-task generation, and runaway iteration unless the system imposes strict stopping criteria and verification gates. Consequently, a gap emerges between open-ended autonomy and the requirements of controlled, evidence-based domains, where reliability, traceability, and bounded behavior are essential.

To address this gap, the proposed prototype (Fig. 10) adopts a structured, verifiable workflow that preserves the practical strengths of ReAct and Auto-GPT while constraining their failure modes.

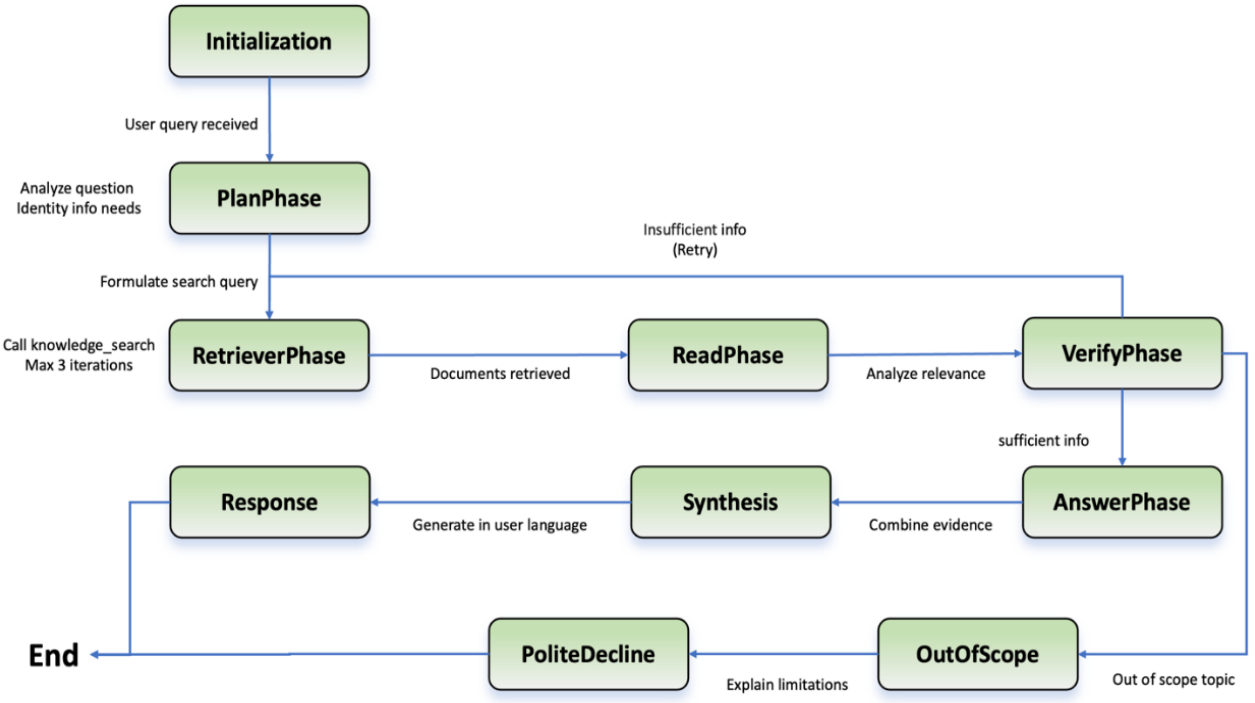

Figure 10 – An Agentic Model of Human–AI Interaction System

Instead of relying on implicit self-judgment, the framework introduces three explicit control mechanisms. First, a dedicated PlanPhase separates intent interpretation from execution by decomposing the information need and defining a retrieval strategy before any tool calls occur. Second, a VerifyPhase functions as a deterministic quality gate. It evaluates whether retrieved evidence is sufficient, consistent, and relevant before generation is allowed to proceed. Third, a scoped retry mechanism enforces bounded autonomy through explicit exit conditions, such as a maximum number of retrieval iterations and well-defined outcomes for out-of-scope requests or insufficient evidence. In effect, the architecture shifts agency from unbounded exploration to controlled autonomy, making it more suitable for high-stakes academic and industrial deployments where knowing when to stop and when to decline is as important as producing an answer.

4. Conclusions

This study provides a comprehensive bibliometric assessment of research on digital transformation within the social sciences and extends this analysis by introducing a conceptual Agentic Model of Human–AI Interaction. Drawing on 389 publications indexed in the Web of Science from 1997 to 2024, the study identifies long-term publication dynamics, conceptual structures, and geographic patterns that shape the field. The analysis reveals that digital transformation research has intensified significantly, particularly in 2021–2022, reflecting its central role in reshaping economic, cultural, and social systems.

Russia, China, Germany, and Ukraine emerge as the leading contributors to this research domain, demonstrating the global relevance of digitalization processes. Influential journals–including Journal of Imaging Science and Technology, Sustainability,

and Social Sciences–underscore the inherently interdisciplinary nature of the field. The thematic mapping uncovers four major research clusters: digital education and innovation, governance and political transformation, methodological and analytical tools, and the growing integration of artificial intelligence into social structures.

A key contribution of this study is the development of an Agentic Model of Human–AI Interaction, conceptualized as a multi-stage system that explains how an AI agent receives, processes, retrieves, and synthesizes information to generate responses. This model reflects broader societal transformations, illustrating how digital systems increasingly operate as autonomous actors within socio-technical environments. The model bridges bibliometric evidence with theoretical insights, demonstrating how emerging technologies reshape human decision-making, institutional practices, and knowledge production.

Despite expanding scholarly interest, the field still faces conceptual fragmentation, geographical imbalance, and insufficient attention to ethical, cultural, and institutional implications of AI-driven digital transformation. Persistent challenges–such as digital inequality, responsible data practices, and the governance of algorithmic systems–require deeper interdisciplinary engagement.

Overall, the study advances academic understanding of how digital transformation and agentic systems co-evolve within the social sciences. It provides an empirical and conceptual foundation for future research, policy development, and educational initiatives aimed at fostering responsible, inclusive, and human-centered digital ecosystems.

Funding

This research was funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant №. BR28713047 Artificial Intelligence and the Ethics of Social Justice: A Conceptual Reflection on Opportunities and Risks in the Processes of Modernization of Society in Kazakhstan)

Author Contributions

Conceptualization, D.Zh. and S.J.; Methodology, D.Zh. and S.J.; Software, D.Zh., A.B.; Validation, D.Zh., A.B. and S.J.; Formal Analysis, D.Zh. and S.J.; Investigation, D.Zh.; Resources, D.Zh.; Data Curation, D.Zh.; Writing – Original Draft Preparation, X.X.; Writing – Review & Editing, D.Zh.; Visualization, D.Zh.; Supervision, D.Zh. and S.J.; Project Administration, S.J.; Funding Acquisition, S.J.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. G. Vial, "Understanding digital transformation: A review and a research agenda," J. Strategic Inf. Syst., vol. 28, no. 2, pp. 118–144, 2019

2. J. Reis, M. Amorim, N. Melão, and P. Matos, "Digital transformation: A literature review and guidelines for future research," in Proc. World Conf. Inf. Syst. Technol., Springer, 2018, pp. 411–421

3. Y. Yeo and S. Jung, "Assessing the economy-wide impacts of digital transformation in the Korean economy: A social accounting matrix multiplier approach," Telecommun. Policy, vol. 48, no. 10, 2024. [Online]. Available: https://doi.org/10.1016/j.telpol.2024.102871

4. X. Guo and W. Pang, "The impact of digital transformation on corporate ESG performance," Finance Res. Lett., vol. 72, 2025. [Online]. Available: https://doi.org/10.1016/j.frl.2024.106518

5. Y. Madani, M. Erritali, J. Bengourram, and F. Sailhan, "Social collaborative filtering approach for recommending courses in an e-learning platform," Procedia Comput. Sci., vol. 151, pp. 1164–1169, 2019. [Online]. Available: https://doi.org/10.1016/j.procs.2019.04.166

6. A. Garzoni, I. De Turi, G. Secundo, and P. Del Vecchio, "Fostering digital transformation of SMEs: A four levels approach," Management Decision, vol. 58, no. 8, pp. 1543–1562, 2020. [Online]. Available: https://doi.org/10.1108/md-07-2019-0939

7. E. R. Banalieva and C. Dhanaraj, "Internalization theory for the digital economy," J. Int. Business Studies, vol. 50, no. 8, pp. 1372–1387, 2019. [Online]. Available: https://doi.org/10.1057/s41267-019-00243-7

8. J. van Dijk, The Digital Divide. Cambridge, UK: Polity Press, 2020.

9. J. R. Bongiovi, "The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power," Social Forces, vol. 98, no. 2, pp. 1–4, 2019. [Online]. Available: https://doi.org/10.1093/sf/soz037

10. V. Eubanks, Automating Inequality: How High-Tech Tools Profile, Police, and Punish the Poor. New York, NY, USA: St. Martin's Press, 2018.

11. L. Floridi et al., "AI4People–An ethical framework for a good AI society: Opportunities, risks, principles, and recommendations," Minds Mach., vol. 28, no. 4, pp. 689–707, 2018, doi: 10.1007/s11023-018-9482-5

12. N. Ridei, W. Wojciech, N. Tytova, L. Stepanenko, and A. Aleksanian, "Digital Transformation of Public Administration: Sociocultural forms of organization in education, science and innovation," Cuestiones Políticas, vol. 40, no. 73, pp. 868–882, 2022. [Online]. Available: https://doi.org/10.46398/cuestpol.4073.50

13. M. Aria and C. Cuccurullo, "bibliometrix: An R-tool for comprehensive science mapping analysis," J. Informetrics, vol. 11, no. 4, pp. 959–975, 2017

14. N. Donthu, S. Kumar, D. Mukherjee, N. Pandey, and W. M. Lim, "How to conduct a bibliometric analysis: An overview and guidelines," J. Business Res., vol. 133, pp. 285–296, 2021.

15. T. Chen, Z. Zhou, and Z. Liu, "Bibliometric analysis on intangible cultural heritage and experience marketing in China," in Design, User Experience, and Usability, Cham: Springer, 2024.

16. R. Y. Maulana and M. Dečman, "Collaborative governance in the digital transformation age: A systematic literature review with bibliometric mapping," Cent. Eur. Public Adm. Rev., vol. 21, no. 1, pp. 31–60, 2023. [Online]. Available: https://doi.org/10.17573/cepar.2023.1.02

17. Z. Van Veldhoven, V. Etikala, A. Goossens, and J. Vanthienen, "A scoping review of the digital transformation literature using scientometric analysis," Business Inf. Syst., pp. 281–292, 2021. [Online]. Available: https://doi.org/10.52825/bis.v1i.49

18. V. Roblek, M. Meško, and I. Podbregar, "Mapping of the emergence of Society 5.0: A bibliometric analysis," Organizacija, vol. 54, no. 4, pp. 293–305, 2021. [Online]. Available: https://doi.org/10.2478/orga-2021-0020

19. E. Stoica, I. Bogoslov, and R. Serbu, "Scientific research perspectives on the relationship between FinTech and education," Int. Rev., no. 1–2, pp. 22–32, 2023. [Online]. Available: https://doi.org/10.5937/intrev2302028S

20. Gürcan, Meltem (2025). Digital Transformation in the Framework of Social Sciences: A Bibliometric Evaluation of the Web of Science Database. Journal of Public Finance Studies, 0(73), 1-17. https://doi.org/10.26650/mcd2025-1598845

21. Wooldridge, Michael, and Nicholas R. Jennings. "Intelligent agents: Theory and practice." *The knowledge engineering review* 10.2 (1995): 115-152.

22. Mussa, Aman, Zhanseit Tuimebayev, and Madina Mansurova. "Make Large Language Models Efficient: A Review." *IEEE Access* (2025). https://doi.org/10.1109/ACCESS.2025.3605110

23. Yang, Hui, Sifu Yue, and Yunzhong He. "Auto-gpt for online decision making: Benchmarks and additional opinions." arXiv preprint arXiv:2306.02224 (2023).

24. Yao, Shunyu, Jeffrey Zhao, Dian Yu, Nan Du, Izhak Shafran, Karthik R. Narasimhan, and Yuan Cao. "React: Synergizing reasoning and acting in language models." In *The eleventh international conference on learning representations*. 2022.

Information About Authors:

Dinara Zhaisanova is a PhD in Innovation management (2022). She is now the acting associate professor of the Department of the Artificial intelligence and Big Data. Her research interests include innovation technologies, management of technologies. ORCID iD: 0000-0002-8116-6111

Sholpan Jamanbalayeva is Doctor of Sociological Sciences, Professor, Deputy General Director for Scientific Work of The Institute of Philosophy, Political Science and Religious Studies of the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan. Her research interests span across interdisciplinary domains involving digital society, sociocultural dynamics, and religion, with a specific geographic focus on Kazakhstan. ORCID iD: 0000-0003-0310-529X

Diana Zhyilussova is a docotral's degree student at the Al-Farabi Kazakh National University in the Department of Artificial Intelligence and Big Data (Almaty, Kazakhstan, zhyilyssovadiana@gmail.com). Her academic interests focus on artificial intelligence and data-driven technologies. ORCID iD: 0000-0001-9211-5224

Ayaulym Baidulla is a docotral's degree student at the Al-Farabi Kazakh National University in the Department of Artificial Intelligence and Big Data. Her academic interests focus on artificial intelligence and data-driven technologies. ORCID iD: 0009-0002-3083-9715

Submission received: 25 November, 2025.
Revised: 19 December, 2025.
Accepted: 19 December, 2025.