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Harapko Dmytro

Postgraduate Student

West Ukrainian National University

ORCID: <https://orcid.org/0009-0000-7566-9663>

THEORETICAL FOUNDATIONS AND INTERDISCIPLINARY CONVERGENCE OF SOCIETY 5.0 FOR SUSTAINABLE DEVELOPMENT

This study investigates whether Society 5.0 is truly a new paradigm or a convergence of established scientific traditions. Using bibliometric analysis of 790 Scopus publications, including keyword co-occurrence mapping and temporal overlay visualisation, we identify a multidimensional conceptual structure comprising five thematic clusters that connect advanced technologies, human-centred design, and sustainability. Temporal analysis shows that Society 5.0 draws on theoretical streams dating back to the 1950s, progressing through three phases: foundational development, interdisciplinary integration, and applied implementation. The study confirms that Society 5.0 is not a revolutionary paradigm but an integrated framework combining mature technological and socio-economic theories, enhancing understanding of its origins and emphasising its importance for human-centred, sustainable development strategies.

Keywords: Society5.0; digital transformation; Industry4.0; human-centred innovation; sustainability transitions.

JEL classification: M15, O33, O35, Q01

Statement of the problem. The concept of Society 5.0, officially introduced by the Japanese government in the Fifth Science and Technology Basic Plan (2016–2020), represents an ambitious vision of a “super-smart society” wherein advanced technologies are seamlessly integrated to address social challenges whilst enhancing human well-being [1] and economic development. Positioned as Japan’s strategic response to Germany’s Industry 4.0 initiative, Society 5.0 articulates a fundamentally different emphasis: rather than focusing on manufacturing efficiency and technological advancement, it foregrounds human-centricity, social inclusivity, and sustainable development [2, 3]. The framework promises to harness cyber-physical systems, artificial intelligence, big data, and the Internet of Things to create a society where economic development and solutions to social problems are achieved in tandem [4].

However, despite the growing international attention to Society 5.0 and its adoption in policy discourse beyond Japan [5, 6], a critical question remains unexplored: to what extent does Society 5.0 constitute a genuinely novel paradigm, and to what extent does it represent a convergence of pre-existing theoretical traditions that have evolved across multiple disciplinary domains? This distinction is not merely academic; understanding the conceptual genealogy of Society 5.0 has significant implications for research agenda-setting, policy implementation, and interdisciplinary collaboration [7].

The rapid proliferation of Society 5.0 literature – from policy documents to academic publications – suggests an urgent need for systematic synthesis [8]. Yet the interdisciplinary nature of the concept presents methodological

challenges for traditional literature reviews. The theoretical underpinnings of Society 5.0 appear to draw upon diverse scholarly traditions: human-computer interaction research from computer science [9], sustainable development frameworks from environmental studies [10], human capabilities approaches from development economics [11], smart cities concepts from urban planning [12], and ethics of technology from philosophy [13]. Without a comprehensive mapping of these intellectual antecedents, the field risks fragmentation, redundancy, and missed opportunities for theoretical integration.

Analysis of recent research and publications. The nascent literature on Society 5.0 can be broadly categorised into three streams. The first comprises policy-oriented analyses that examine Japan’s strategic objectives and implementation frameworks [14, 15]. These studies illuminate the governmental rationale and institutional mechanisms but rarely interrogate the concept’s theoretical foundations. The second stream focuses on technological dimensions, exploring how specific innovations in the Internet of Things [17], robotics [18] – contribute to the realisation of Society 5.0. Whilst valuable, these contributions tend to adopt a technology-deterministic perspective that underestimates the social and ethical complexities inherent in the vision.

The third, more recent stream attempts broader conceptual analyses, positioning Society 5.0 within frameworks of digital transformation [19], sustainable development [20, 21], or socio-technical transitions [22]. A. Deguchi et al. [23] provide a notable exception by tracing Society 5.0’s intellectual lineage to systems thinking and cybernetics.



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Yet, their analysis remains limited in scope and lacks empirical grounding in systematic literature analysis. Similarly, M. Fukuyama [24] and B. Salgues [25] offer historical contextualisation but do not employ rigorous

Several established research traditions exhibit remarkable conceptual alignment with Society 5.0's core tenets, suggesting potential theoretical antecedents:

- **Human-Centred Technology Design:** The human-computer interaction field has long advocated for technology that augments rather than replaces human capabilities [26, 27]. Norman's design principles [28] and participatory design methodologies [29] prefigure Society 5.0's emphasis on human-centricity decades before the term emerged.
- **Sustainable Development Discourse:** From the Brundtland Report [30] through the Millennium Development Goals [31] to the current Sustainable Development Goals framework [32], there exists a substantial body of literature on balancing economic progress with social equity and environmental sustainability
- **Cyber-Physical Systems and Smart Cities:** The conceptualisation of deeply integrated digital-physical systems [33] and intelligent urban environments [34, 35] provides technological and organisational blueprints consonant with Society 5.0's implementation strategies.
- **Capabilities Approach and Quality of Life:** A. Sen [36] and M. Nussbaum [37] capabilities approach, emphasising human flourishing beyond economic metrics, aligns philosophically with Society 5.0's goal of enhancing quality of life rather than merely pursuing GDP growth.
- **Socio-Technical Systems Theory:** Established frameworks examining the co-evolution of technology and society [38, 39] offer analytical tools for understanding Society 5.0 as a systemic transformation rather than isolated technological change.

Despite these apparent connections, existing scholarship exhibits three critical limitations. First, there is no systematic empirical analysis demonstrating how these diverse theoretical traditions actually converge in Society 5.0 discourse. Second, the temporal dynamics remain unexplored: when and how did different disciplinary streams begin intersecting? Third, the geographical and institutional dimensions of knowledge production are unclear: which academic communities, regions, and collaborative networks are driving Society 5.0 research, and what does this reveal about potential blind spots or underrepresented perspectives?

Bibliometric methodologies offer powerful tools to address these gaps. Yet, to date, no comprehensive bibliometric study has been conducted on Society 5.0 literature, representing a significant methodological gap in understanding this emerging paradigm.

Objectives of the article. This study aims to conduct a comprehensive bibliometric analysis of Society 5.0 literature to: (1) map the intellectual structure and theoretical foundations underlying Society 5.0 research; (2) identify and characterise the disciplinary origins and temporal evolution of key conceptual streams that converge in Society 5.0 discourse; (3) reveal patterns of interdisciplinary collaboration and knowledge integration; and (4) identify research gaps and future directions for Society 5.0 scholarship.

Specifically, the research addresses the following questions:

- What are the foundational theoretical traditions that inform Society 5.0 research across disciplines?

• How has the conceptual landscape evolved temporally, and when did key disciplinary convergences emerge?

• Which geographical regions, institutions, and research communities dominate knowledge production, and what are the implications for global representation?

• What are the principal thematic clusters within Society 5.0 literature, and how do they interconnect?

• Which research areas remain underexplored, and where do opportunities for theoretical integration exist?

Summary of the main research material. This study employs a mixed-methods bibliometric approach, combining quantitative analysis with qualitative interpretation. The methodology comprises such stages:

Stage 1: Data Collection Bibliographic data were systematically retrieved from the Scopus database for the period 2016–2024. The search strategy employed two complementary approaches: (a) direct searches using the term “Society 5.0” and its variants; and (b) indirect searches combining keywords representing core Society 5.0 concepts (e.g., “human-centric technology”, “super smart society”, “cyber-physical systems” AND “social challenges”). Inclusion criteria required peer-reviewed journal articles and conference proceedings in English. Grey literature and policy documents were excluded to maintain analytical focus on academic discourse, though key governmental publications were consulted for contextual understanding.

Stage 2: Bibliometric analysis, multiple bibliometric techniques were applied using VOSviewer and the Bibliometrix R package.

The rapid expansion of scholarly work on Society 5.0 becomes immediately evident when examining the trajectory of annual publications. Although the concept entered public discourse only in 2016 (Figure 1, growth between 2020 and 2024 was particularly pronounced, reflecting the intensification of global debates over digital transformation, human-centric innovation, and socio-technological resilience.

The figure shows a sharp rise in publication volume beginning in 2020, indicating the consolidation of Society 5.0 as a stable and expanding research domain. This overall growth corresponds to a substantial semantic diversification within the field. Author keyword frequencies reveal a dense cluster of thematic anchors that bridge digital technologies, sustainability imperatives and societal concerns. As depicted in Figure 2, “society 5.0” dominates the lexicon, followed by “industry 4.0,” “industry 5.0,” “artificial intelligence,” “sustainability,” “IoT”, and “digital transformation.” The simultaneous presence of foundational digitalisation concepts, sustainability terminology and human-centric themes suggests that Society 5.0 has evolved into a hybrid socio-technical paradigm that integrates diverse trajectories of technological and societal development.

The barplot shows the dominance of hybrid technological-societal terms, indicating the multidimensional nature of the conceptual structure. This conceptual hybridity is mirrored in the global distribution of contributions. Figure 3 illustrates that Indonesia leads in the number of affiliated authors, surpassing Japan – the birthplace of the concept. Such diffusion dynamics highlight Society 5.0's flexibility as a development framework: emerging economies adopt it to articulate technologically enabled strate-

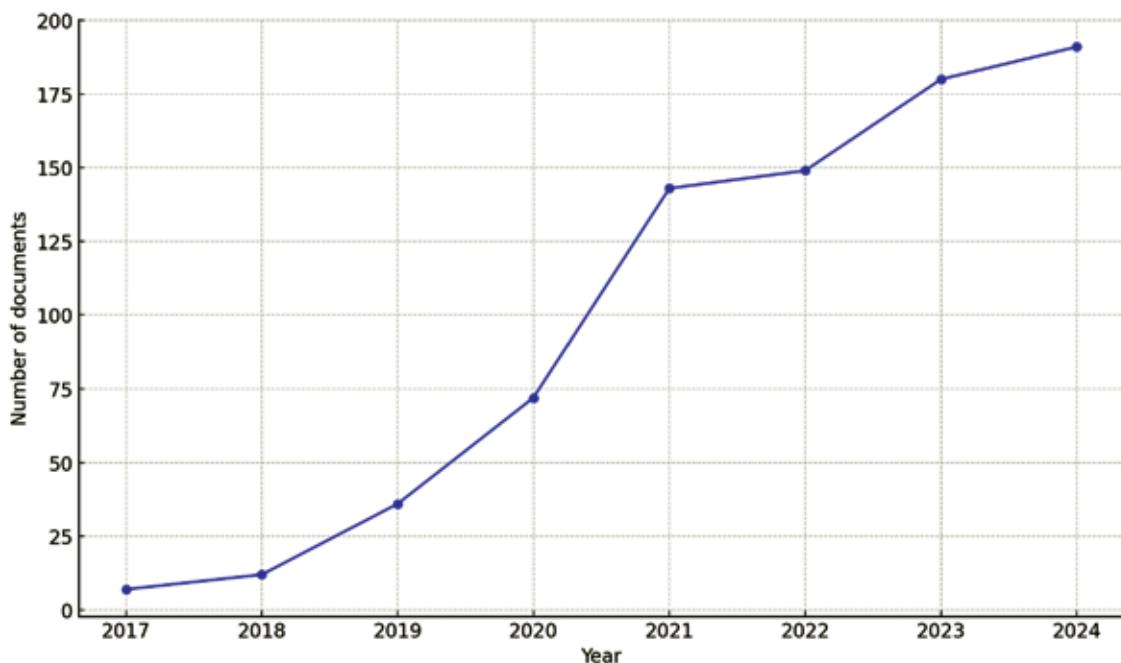


Figure 1 – Annual publication trends in Society 5.0 research (2017–2024)

Source: author calculation with the Bibliometrix package

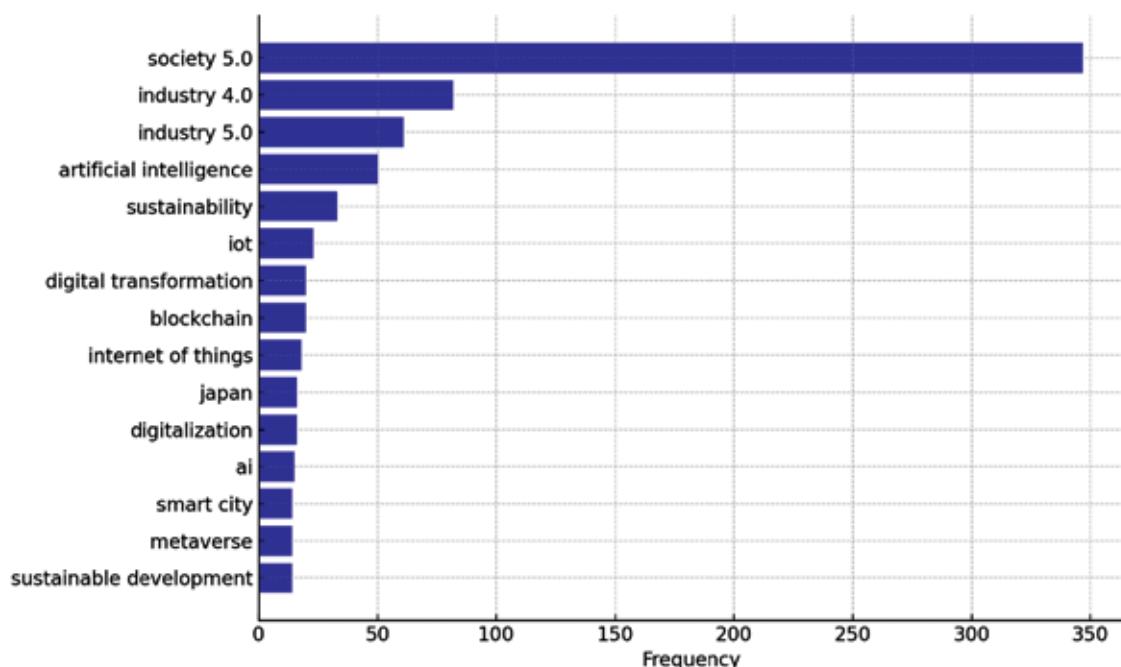


Figure 2 – Most frequent author keywords in Society 5.0 publications.

Source: author calculation with the Bibliometrix package

gies for education, governance and human capital formation. Meanwhile, contributions from technologically advanced countries (Japan, USA, Italy) and EU member states (Portugal, Poland) demonstrate that Society 5.0 resonates across diverse institutional and economic contexts.

Indonesia and Japan lead the global output, followed by India, the United States and European countries, confirming the paradigm's transnational adaptability. Beyond

geographical diffusion, the historical depth of the field is revealed by analysing the publication years of cited references. Figure 4 demonstrates that the intellectual roots of Society 5.0 extend far before its formal introduction: references span from the 1950s through to the present [23], with significant increases during the 1970s (systems theory, cybernetics [23]), the 1990s (knowledge society [4], innovation theory [5]) and the 2010s (AI, IoT, big

data). The sharp rise after 2010 corresponds to the global digitalisation wave, which later provided the technological foundation for the emergence of Society 5.0.

The figure shows a deep intellectual lineage, indicating that Society 5.0 synthesises decades of socio-technical thinking.

The intensity with which these references are used is shown in Figure 4, which charts how frequently the corpus

cites works from different years. The curve peaks sharply around 2021–2022, aligning with the period of strongest publication growth. This synchronisation between the citing and cited corpora underscores the co-evolution of Society 5.0 with broader digital transformation [19] and sustainability scholarship [10, 20, 32].

A complementary perspective on the field's intellectual structure emerges from examining the most prolific

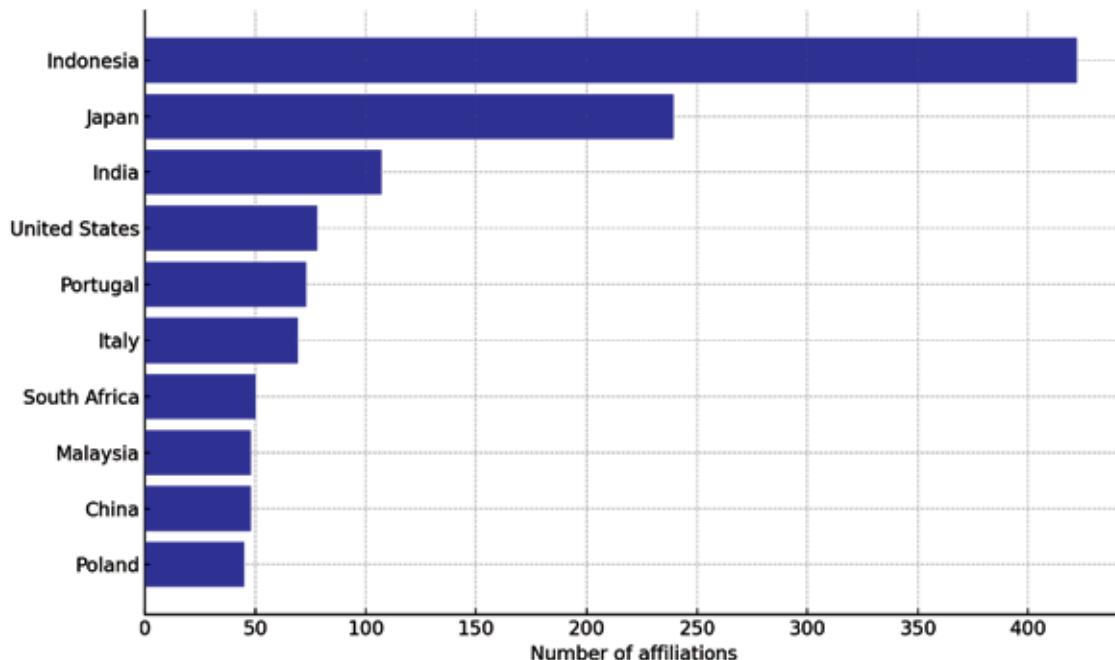


Figure 3 – Geographical distribution of author affiliations.

Source: author calculation with the Bibliometrix package

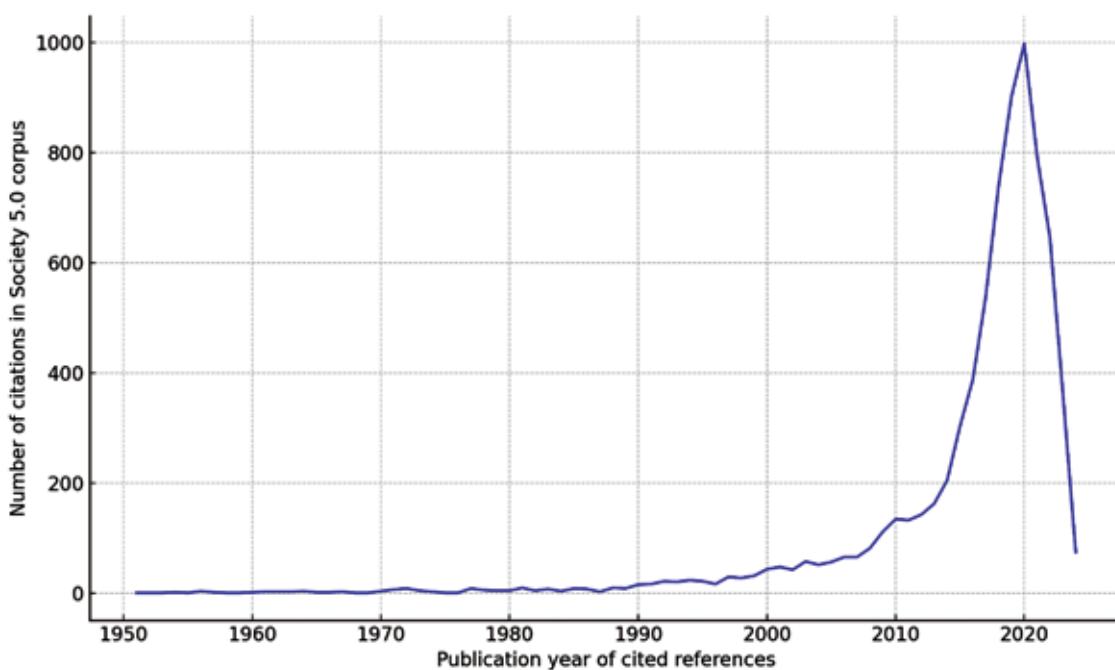


Figure 4 – Chronological distribution of cited references (1950–2024).

Source: author calculation with the Bibliometrix package

authors in Society 5.0 scholarship. While the geographic distribution reveals where research activity is located, the author-level analysis identifies who drives conceptual development and methodological innovation, in addition to published works [20–38]. The top contributors listed in Table 1 represent a diverse set of disciplinary backgrounds – industrial engineering, cyber-physical systems, innovation management, information systems, and socio-technical design – indicating that the field is shaped by multiple epistemic communities rather than a single dominant school of thought.

The distribution of leading authors demonstrates several critical characteristics of the Society 5.0 research landscape. First, the absence of a single overwhelmingly dominant author indicates a decentralised intellectual ecosystem. Such a structure is typical of emerging interdisciplinary paradigms, in which conceptual foundations are laid by multiple research traditions in parallel.

Second, the presence of scholars such as E. G. Carayannis and H. Smuts [5], known for their contributions to innovation systems, digital transformation, and socio-technical governance, underscores that Society 5.0 is frequently interpreted within the broader context of human-centred innovation policy and knowledge-based development. Society 5.0 to longer-standing debates on sustainable [10, 32] and inclusive technological change [9, 13].

Third, the inclusion of Y. Masuda – whose foundational ideas on the information society [4] predate the Socie-

ty 5.0 terminology by several decades – demonstrates the profound historical continuity of the paradigm. Y. Masuda [4] serves as an intellectual bridge between early information society theory and contemporary socio-digital transformation frameworks. His presence in the top 10 list reinforces the argument that Society 5.0 has far older epistemic roots than its 2016–2017 policy origins suggest.

Fourth, contributors such as J. Amadi-Echendu, D. Mourtzis, and F.-Y. Wang represent the engineering and cyber-physical systems [33] communities, emphasising the technological underpinnings of the paradigm. Their work links Society 5.0 to manufacturing futures, intelligent systems, decision-support architectures, and cyber-physical integration.

Fifth, authors such as M. Nakamura, S. Saiki and E. Schoitsch contribute from the perspective of safety-critical systems, human–machine collaboration and standardisation, indicating that Society 5.0 is also interpreted as a regulatory and socio-technical design challenge rather than solely as a technological one.

Collectively, the author-level analysis supports the broader conclusion drawn from keyword and network analysis: Society 5.0 is not dominated by a single theoretical school but emerges from the convergence of multiple, long-standing intellectual traditions. The distribution of contributions across innovation studies, engineering, cyber-physical systems, information science and socio-technical design reinforces the interpretation of Society 5.0 as a synthesis

Table 1 – Top 10 most prolific authors in the Society 5.0 corpus (N=790 documents).

No	Author	Number of documents	Subject Area within Society 5.0 Corpus	Research Trajectory (as reflected in Society 5.0 publications)
1	Carayannis, E.G.	11	Innovation studies; knowledge systems; socio-technical policy	Bridges Society 5.0 with human-centred innovation, sustainable development, entrepreneurial ecosystems and Quadruple/ Quintuple Helix models. [5]
2	Smuts, H.	11	Information systems; digital transformation; knowledge management	Focuses on organisational digitalisation, knowledge governance, human–technology integration and socio-technical transitions.
3	Y.Masuda	10	Information society theory; socio-economic futures	Provides historical continuity from early information society concepts to contemporary human-centric, post-industrial societal models informing Society 5.0.
45	J. Amadi-Echendu	10	Engineering assets; systems engineering; cyber-physical integration	Connects physical – digital system design, asset management and smart manufacturing to Society 5.0's technological foundations.
6	F.-Y. Wang	7	Intelligent systems; AI-driven cybernetics; intelligent control	Advances AI-enabled decision systems, autonomous intelligence, and computational governance aligned with Society 5.0's socio-technical vision.
7	M. Nakamura	7	Human–machine collaboration; robotics; socio-technical safety	Explores robotics, assistive systems, safety architectures and human-centric human-machine interfaces within Society 5.0 contexts.
8	D. Mourtzis	7	Smart manufacturing; Industry 4.0/5.0; digital twins	Positions Society 5.0 within advanced manufacturing, simulation modelling, digital twins and intelligent production environments.
9	S.Saiki	6	ICT-enabled public services; digital governance	Focuses on human-centred service delivery, ICT-enabled governance systems, and socio-10 digital innovation aligned with Society 5.0 goals.
	E. Schoitsch	6	Safety-critical systems; standards; cyber-security	Links Society 5.0 to dependable systems engineering, standardisation, trustworthiness and safety assurance of cyber-physical ecosystems.
	J. Angelopoulos	6	Smart cities; IoT ecosystems; urban innovation	Develops Society 5.0 applications in smart cities, IoT-enabled public infrastructures and citizen-centric innovation pathways.

Source: author calculations from Scopus dataset [39]

rather than an invention. The leading authors thus function as “intellectual anchors” stabilising different facets of the paradigm – technological, social, organisational, and normative – within a shared conceptual space.

These macro-level patterns provide the necessary framework for interpreting the conceptual and temporal structure revealed through VOSviewer analysis. The keyword co-occurrence network (Figure 5) depicts Society 5.0 [1] as a structurally central integrator of five major thematic clusters. The red cluster centres on educational innovation [14] and human-centric development [9]; the yellow cluster reflects Industry 4.0 digital infrastructures [2]; the green cluster emphasises sustainability [10, 32] and Industry 5.0 [5]; the blue cluster depicts cyber-physical systems [33] and enabling technologies such as blockchain and 5G; and the purple frontier reflects AI-driven applications [16] and domain-specific digitalisation [19]. The network's topology demonstrates that Society 5.0 functions as a bridging device connecting technological foundations with societal and sustainability imperatives.

Five clusters reveal the multi-layered conceptual architecture linking digital technologies, human-centric innovation and sustainability.

The temporal overlay map in Figure 6 further clarifies how these themes unfold over time. Early concepts (blue/purple) – such as IoT, embedded systems and industrial economics – represent the pre-existing substrate inherited from Industry 4.0 and earlier digitalisation theories. Mid-period concepts (green/teal), including Society 5.0 itself, reflect the conceptual consolidation phase during 2021–2022, when technological, sustainability, and human-centric framings converge. The yellow frontier, dominated by big data, digital twins, machine learning, healthcare and smart cities [12,

34, 35], marks the current trajectory of applied implementation. This chromatic stratification demonstrates that Society 5.0 has evolved through three sequential phases: foundational technological development, integrative conceptual synthesis and applied operationalisation.

Taken together, results present a coherent narrative of the emergence, diffusion and deepening of Society 5.0 as an interdisciplinary socio-technical paradigm. Its rapid publication growth, conceptual hybridity, global adoption, historical lineage, intellectual intensity, and semantic-temporal structure confirm that Society 5.0 is not a novel technological model but a synthetic framework that reorganises mature theoretical traditions around the shared objective of building human-centred, sustainable and digitally enabled societies. The paradigm's strength lies in its integrative capacity – binding together innovation systems, sustainability transitions and digital transformation into a unified narrative for future societal development.

Conclusions. This study clarifies the theoretical roots, interdisciplinary background, and evolution of Society 5.0. First, it shows that Society 5.0 is not a sudden innovation but is built on 7 decades of scholarship in fields such as systems theory, cybernetics, information studies, innovation, socio-technical transitions, sustainability, and digital transformation. The references analysis indicates that Society 5.0 synthesises ideas that predate its 2016–2017 policy debut. First of all, the study concludes that Society 5.0 is best seen as a synthetic, integrative paradigm rather than a disruptive novelty.

Second, the findings clarify the internal structure and conceptual logic of Society 5.0. The five-cluster network from the co-occurrence analysis shows that Society 5.0 is built on three key pillars: (1) technological infrastructures (AI, IoT, CPS, digital twins), (2) human-centred innovation

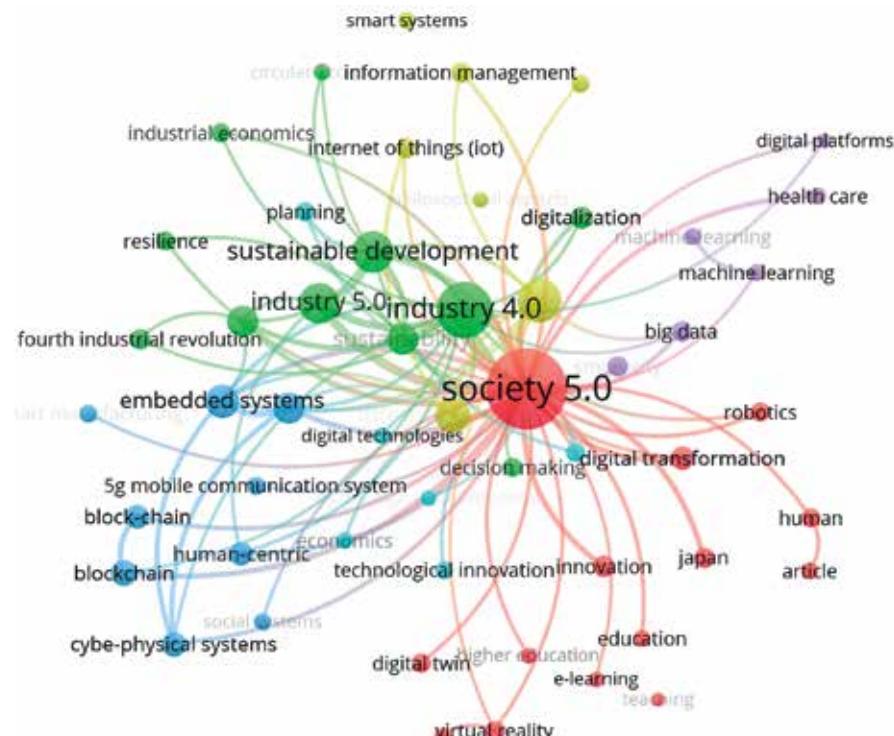


Figure 5 – Keyword co-occurrence network

Source: developed by the author using VOSviewer

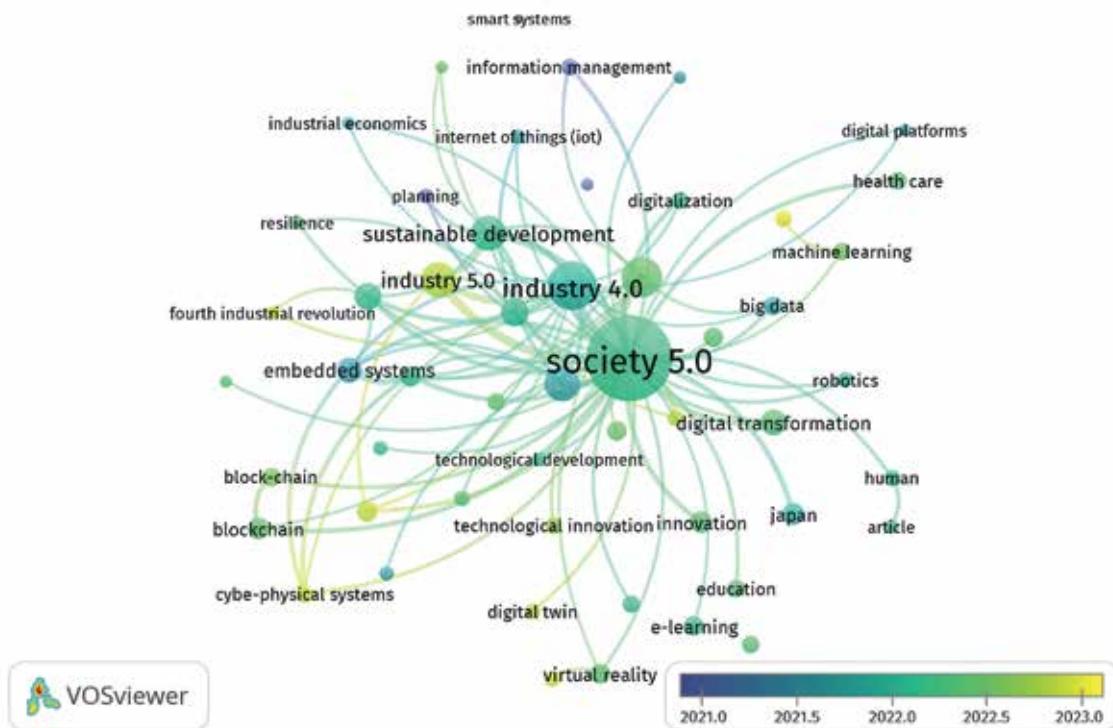


Figure 6 – Temporal evolution of Society 5.0 concepts (VOSviewer overlay)

Source: developed by the author using VOSviewer

and socio-technical design, and (3) sustainability transitions. This advances theoretical clarity, often missing in descriptive or policy-focused Society 5.0 literature.

Third, our results improve understanding of the field's interdisciplinary nature: it is not Japan-dominated or confined to a single discipline. Instead, Society 5.0 research stems from a global network spanning engineering, innovation studies, information systems, and socio-technical governance, demonstrating its true transnational and interdisciplinary nature.

Fourth, the study contributes to the academic literature by identifying and empirically validating a three-phase developmental trajectory of Society 5.0: (1) the foundational phase (1950s–2010s), (2) the convergence phase (2021–2022), and (3) the application phase (2022 onwards). By reconstructing this trajectory, the study fills a significant gap in the theoretical literature, which until now lacked a systematic, evidence-based account of how Society 5.0 emerged, evolved and consolidated.

Fifth, integrating bibliometric techniques with conceptual analysis provides a methodological contribution. Much of the existing Society 5.0 scholarship is conceptual, narrative or normative; this study introduces a rigorous empirical

mapping that reveals structural, temporal and geographical patterns not previously documented. The approach used here thus extends the methodological toolkit available for researching socio-technical paradigms. It can be applied to related concepts such as Industry 5.0, smart, sustainable cities, and human-centred AI.

Finally, the findings have practical implications. The study shows that Society 5.0 is grounded in established technological and socio-economic research, reassuring policymakers and practitioners seeking solid frameworks to guide digital transformation. Its integrative structure – connecting innovation, sustainability, and human well-being – lays a strong foundation for governance, education, industry, and smart city strategies that prioritise societal value over technology alone. This clarifies Society 5.0's practical relevance and legitimacy as a framework for modern socio-digital transitions.

In summary, this research provides clear empirical evidence that the value of Society 5.0 lies not in novelty but in its ability to integrate and build upon mature theories. By explicitly demonstrating this integration, the study offers clarity, rigour, and practical insights, thereby significantly contributing to academic and policy discussions on sustainable, human-centred, digitally enabled futures.

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Гарапко Д.А.
Західноукраїнський національний університет

ТЕОРЕТИЧНІ ЗАСАДИ ТА МІЖДИСЦИПЛІНАРНА КОНВЕРГЕНЦІЯ КОНЦЕПЦІЇ СУСПІЛЬСТВО 5.0 ДЛЯ СТАЛОГО РОЗВИТКУ

Стаття присвячена науковому узагальненню теоретичних засад та міждисциплінарної конвергенції концепції Суспільство 5.0, яка стрімко поширюється у світовій академічній і політичній риториці, але досі позбавлена чітко окресленого теоретичного підґрунтя та систематичного емпіричного аналізу її інтелектуальних витоків. Мета статті полягає у ідентифікації інтелектуальної генеалогії, структурних характеристик і динаміки розвитку концепції на основі системного бібліометричного аналізу міжнародної академічної літератури. Методологія дослідження поєднує кількісні інструменти VOSviewer i Bibliometrix з якісною інтерпретацією результатів, охоплюючи аналіз продуктивності публікацій, профілювання ключових авторів і географічних регіонів, мережею

карту ключових слів, часові накладення та детальну хронологію джерел. Отримані результати показують, що Суспільство 5.0 не є новим теоретичним утворенням або революційною інновацією, а окреслено як синтетична рамка, що інтегрує довготривалі наукові традиції — від теорії систем та кібернетики 1950-х років до сучасних концепцій сталого розвитку, інноваційної економіки, цифрової трансформації й соціально-технічних переходів. Виявлено триетапну еволюцію парадигми: формування теоретичних основ, міждисциплінарну конвергенцію та сучасну фазу прикладної імплементації, орієнтовану на AI-активовані, кібер-фізичні та міські цифрові рішення. Просторовий аналіз засвідчив глобальне розширення концепції за межі японського контексту та відсутність єдиного домінантного інтелектуального центру, що підтверджує поліцентричний та міждисциплінарний характер парадигми. Наукова новизна статті полягає у першій всебічній реконструкції теоретичних витоків концепції Суспільство 5.0 та емпіричному доведенні її інтегративної природи на основі систематичного бібліометричного аналізу. Практичне значення полягає в тому, що Суспільство 5.0 постає як науково обґрунтована узагальнювальна рамка для формування політик людиноцентричної, технологічно орієнтованої трансформації суспільств у межах парадигми сталого розвитку.

Ключові слова: Суспільство 5.0, цифрова трансформація, Індустрія 4.0, людиноцентричні інновації, переходи до сталого розвитку.

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