

Industry 5.0. and Sustainable Innovation: the role of the organizational framework in fostering innovation

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Abstract.

Industry 5.0 is defined by the incorporation of organizational principles and technological advancements to create systems that are environmentally friendly, adaptable, and focused on meeting human needs. Despite the explanation of Industry 5.0, its potential impact on management activities and organizational innovation remains largely unexplored. This article examines the field's knowledge structure to present a framework that examines whether business organizations can drive innovation by benefiting from Society 5.0 principles and utilizing Industry 5.0 technology.

We utilized the WOS and Scopus databases to perform three separate keyword searches on Industry 5.0, Society 5.0, and Innovation 5.0. We conducted a keyword analysis on 968 articles related to Industry 5.0, 297 articles related to Innovation 5.0, and 510 articles related to Society 5.0, all of which fall under the business management category. This was followed by a systematic literature review to determine the components of the proposed framework that would lead to Innovation 5.0 and sustainability through organizational activity.

This research aims to establish a framework that assists organizations in fostering sustainability through Innovation 5.0 by leveraging Industry 5.0 technologies and opportunities and benefiting from the existence of Society 5.0 and smart cities. The framework also lays the groundwork for future research that examines the impact of the fifth industrial revolution on organizational activities.

Keywords: Industry 5.0, Innovation 5.0, Smart Cities, Society 5.0, Sustainability

1 Introduction

The term 'Industry 5.0' was introduced by the European Commission to characterize the move towards a more human-centered, resilient, and sustainable industry [1]. In Industry 5.0, humans play a crucial role in the manufacturing process by utilizing problem-solving skills, emotional intelligence, and creativity. Machines, on the other hand, offer precision, speed, and data analysis to develop innovative products and tailored solutions for consumers. Exploring the combination of machines and humans opens up new avenues for personal growth, education, and creativity [2].

Society 5.0 proposes a future where technological advancements integrate seamlessly into daily life [3]. This society places a strong emphasis on the well-being of its citizens, employing various technologies like robotics, Artificial Intelligence (AI), and the Internet of Things (IoT) to tackle societal problems and enhance the overall quality of life [4]. Innovation 5.0, however, pertains to the mindset and approach necessary to propel this societal transformation by thinking innovatively, constantly improving, and effectively managing information to innovate and ensure sustainable development [3].

Research on Industry 5.0 is still in its early stages but is rapidly increasing [5]. Previous studies have delved into different facets of the early phase of Industry 5.0 [6], contributing significant insight on Industry 5.0 enabling technologies [7], transition towards Society 5.0 [3], and innovation[8]. The main focus of these studies has been on enabling technologies, with limited research specifically addressing Industry 5.0, Innovation 5.0, and Society 5.0 and their implications for management and organizations, despite the importance of these concepts and their effects on organizations and their operations. This research gap limits our comprehension of the strategies and approaches that organizations can implement to successfully adopt Innovation 5.0.

Analyzing and comprehending the principles of Industry 5.0, Society 5.0, and Innovation 5.0 is crucial in the field of business management, given their significant impact on businesses. Technological developments and the imperative for sustainable growth, perceived as the ultimate objective of organizations, propel the future progression of enterprises and society.

By adopting a systematic literature review, this research aims to establish a framework that assists organizations in advancing Innovation 5.0 and triple bottom line sustainability by leveraging Industry 5.0 technologies and opportunities and benefiting from the existence of Society 5.0. The framework also lays the groundwork for future research that examines the impact of the fifth industrial revolution on organizational activities.

2 Literature Review

The transition to Industry 5.0 involves a focus on emerging technologies and methodologies that emphasize human interaction and collaboration [2]. This requires

businesses to reassess conventional hierarchical structures, operations and employee skills to adapt to the required changes [9] to meet customers' needs [2], besides aligning their practices with sustainability and social responsibility principles [10]. Industry 5.0 also impacts smart cities through by managing resources and service delivery [11]. Smart cities utilize technology and data to improve efficiency, sustainability, and quality of life for their residents [12]. Innovation 5.0 takes this concept a step further by incorporating cutting-edge technologies to create smarter and more connected cities that drive economic growth [13].

Within this framework, Society 5.0 strives to merge technology with human capabilities and needs to enhance the quality of life for individuals and communities [4]. In this scope, smart cities play a key role in ensuring that the infrastructure and services are efficient, sustainable, and responsive to the needs of Society 5.0. Accordingly, a strong partnership should exist between the public and private sectors, with governments playing a crucial role in setting ethical technology policies and building infrastructure [13].

Innovation 5.0 and Industry 5.0 are symbiotic concepts, Innovation 5.0 develops and implements cutting-edge technologies, while Industry 5.0 pushes technological boundaries [8]. This collaboration leads to the establishment of smart organizations and intelligent systems that automate tasks, optimize production processes, and improve operational efficiency, leading to a higher-level decision-making and a creative human role [14]. The convergence of human skills and advanced technologies leads to a more productive and sustainable future by creating new job opportunities and investments that lead to economic growth [8].

Incorporating Industry 5.0, Society 5.0, and Innovation 5.0 principles into their operations allows organizations to adapt to the changing landscape of business and technology and drive innovation. This approach not only boosts organizational performance but also fosters a culture of continuous improvement and adaptability. Based on this assumption, this research aims to answer the following research questions:

- How can business organizations drive innovation by benefiting from Society 5.0 principles and utilizing Industry 5.0 technology?

Answering these research questions will allow us to set a basic framework that allows researchers to identify Industry 5.0, Society 5.0, and Innovation 5.0 factors and technologies in business and management fields. It will also provide knowledge for practitioners to understand how the evolution of Industry 5.0 and Society 5.0 may affect organizational activities to drive Innovation 5.0 and ensure triple bottom line sustainability.

3 Methodology

To better understand the literature related to the Industry 5.0, Innovation 5.0, and Society 5.0 pillars, we use both Scopus and WOS databases as well as VOS software to

deduce clusters to identify literature and provide a comprehensive overview of topics related to these different concepts. Consequently, we arranged the search using the specified keywords and logic shown in Figure 1. In each database, we conducted independent searches for Industry 5.0, Innovation 5.0, and Society 5.0, respectively.

The results were filtered to exclude research areas that are not directly related to our theme. Thus, management, business, accounting, economy, finance, decision-making sciences, and hospitality have been selected as relevant categories and areas of research for further analysis. Afterwards, we combined both the extracted entries (i.e., bibliometric information) from the two databases into an Excel sheet to compare the list of publications and unify the entries. After identifying the same indexed publications in both databases and excluding preambles, the final list of publications to be analyzed included 968 articles pertaining to Industry 5.0, 297 articles pertaining to Innovation 5.0, and 510 articles pertaining to Society 5.0. In addition, we manually checked keywords and corrected discrepancies.

The unified search results are imported into the VOS viewer software, which is a standard tool for reviewing literature [15-16]. The results will be presented in the following section.

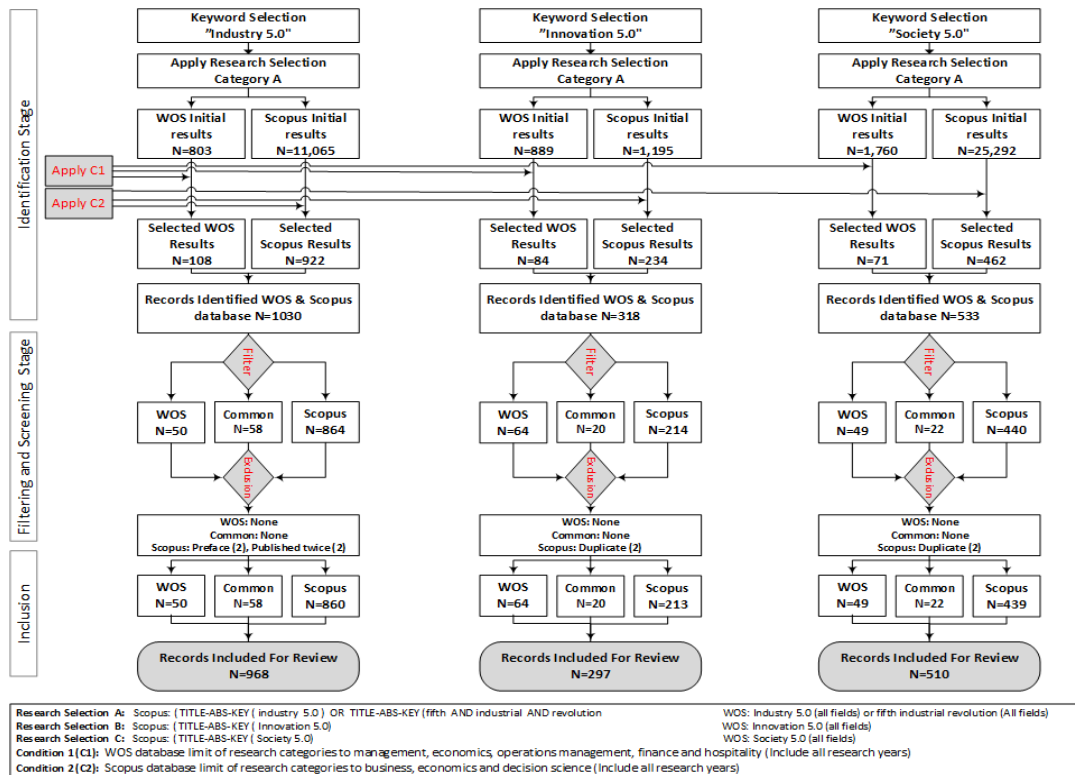


Fig.1. Prisma Diagram of Inclusion Criteria

4 Findings

4.1 Industry 5.0 Clusters Analysis

Analyzing co-occurrences with a minimum threshold of five occurrences was the first step in creating the keyword maps. Out of the 6300 terms, only 62 satisfied the conditions. Terms unrelated to the field of study, like chemistry, are also omitted. Hence, the map illustrated in Figure 2 depicts the formation of 10 clusters that signify key aspects of Industry 5.0, whereas Table 1 highlights the primary connections between nodes and keywords within clusters.

The cluster analysis yielded remarkable findings. Initially, the clusters encompassed a significant portion of the dimensions associated with Industry 5.0 and Industry 4.0, which are seen as interconnected [17]. Furthermore, the keywords sustainability, AI, Society 5.0, digital transformation, human factors, IoT, and blockchain played a significant role in connecting the clusters. Besides, the analysis revealed distinct clusters of organizational keywords, including supply chain management, manufacturing, skills, career, human resources management, automation, robotics, etc. These keywords were notably linked to the concept of Industry 5.0. Additionally, there were other societal concepts such as education, knowledge management, and health care that are connected with sustainability, innovation, and Industry 5.0. Furthermore, the Industry 5.0

keyword induced a connection with several clusters and with different categories. For example, with respect to human and societal keywords, Industry 5.0 showed a connection with keywords such as sustainability, education, and human factors, as well as with organizational keywords such as career, skills, human resource management, knowledge management, employment, supply chain, innovation, and decision-making. Furthermore, Industry 5.0 showed a strong connection with smart cities, Society 5.0, and super-smart society.

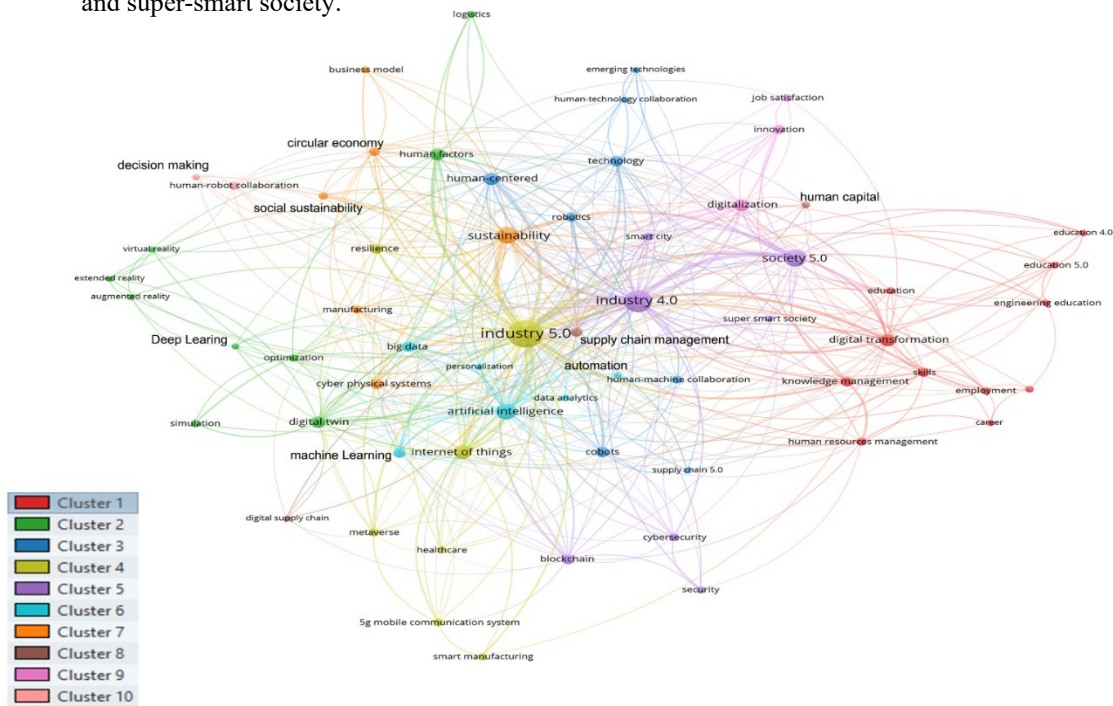


Fig. 2. Industry 5.0 Clusters

Table 1. Industry 5.0 and Industry 4.0 Nodes Connection

Main Node (Cluster)	Connection With Cluster	Keywords (Frequency of Occurrence)
Industry 5.0 (291) Cluster 4	1	Digital Transformation (31); Knowledge Management (15); Skills (13); Human Resources Management (10); Employment (7); Education (6); Higher Education (6); Education 5.0 (6); Engineering Education (6); Education 4.0 (5); Career (5).
	2	Digital Twin (27); Human Factors (25); Optimization (8); Simulation (7); Logistics (6); Deep Learning (5); Augmented Reality (5); Extended Reality (5); Virtual Reality (5).
	3	Human-Centered (31); Cobots (19); Technology (19); Robotics (13); Human-Machine Collaboration (9); Supply Chain 5.0 (5); Human-Technology Collaboration (5).
	5	Industry 4.0 (156); Society 5.0 (80); Smart City (9); Super Smart Society (6).
	6	Artificial Intelligence (61); Big Data (20); Machine Learning (16); Data Analytics (6); Automation (5); Personalization (5).
	7	Sustainability (73); Cyber Physical Systems (16); Circular Economy (12); Manufacturing (9); Social Sustainability (7); Business Model (6).
	8	Supply Chain Management (14); Digital Supply Chain (5).
	9	Digitalization (32); Innovation (13).
	10	Human-Robot Collaboration (11); Decision Making (5).
Industry 4.0 (156) Cluster 5	1	Digital Transformation (31); Knowledge Management (15); Skills (13); Human Resources Management (10); Employment (7); Education 5.0 (6); Engineering Education (6); Education 4.0 (5).
	2	Digital Twin (27); Human Factors (25); Optimization (8); Simulation (7); Logistics (6); Deep Learning (5); Augmented Reality (5); Extended Reality (5).
	3	Human-Centered (31); Cobots (19); Technology (19); Robotics (13); Human-Machine Collaboration (9); Supply Chain 5.0 (5); Human-Technology Collaboration (5); Emerging Technologies (5).
	4	Industry 5.0 (291); Internet of Things (47); Resilience (16); 5g Mobile Communication Systems (9); Healthcare (6);
	6	Artificial Intelligence (61); Internet of Things (47); Big Data (20); Data Analytics (6); Personalization (5).
	7	Sustainability (73); Cyber Physical Systems (16); Circular Economy (12); Manufacturing (9); Social Sustainability (7); Business Model (6).
	8	Supply Chain Management (14), Digital Supply Chain (5).
	9	Digitalization (32), Big Data (20); Job Satisfaction (9); Automation (5).
	10	Human-Robot Collaboration (11); Decision Making (5).

4.2 Society 5.0 Clusters Analysis

We conducted the test again using identical criteria. Among a total of 2605 keywords, only 46 satisfied the requirement of having at least five occurrences. The map in Figure 3 shows the development of nine clusters representing important aspects of Society 5.0, while Table 3 emphasizes the main connections between nodes and keywords in the clusters.

With respect to the cluster contents, first, Industry 5.0 and Industry 4.0 technological keywords, along with organizational keywords (i.e., human resources management, skills), were accumulated in one cluster. Second, smart cities, knowledgeable society, and circular economy keywords also existed in one cluster and were connected to Industry 5.0, sustainability, Society 5.0, and innovation keywords. Third, sustainability, education, e-learning, resilience, AI, and ethics keywords were accumulated in one cluster and connected to the main nodes of other clusters.

Furthermore, Society 5.0 showed a strong connection with the Industry 5.0 cluster and its keywords pertaining to technological factors. Also, Society 5.0 indicated a connection with organizational keywords such as human resources management, risk management, skills, employment, SMEs, technological innovation, intellectual capital, and enterprise architecture. Besides, the Society 5.0 keyword indicated a connection with the societal keyword's education, e-learning, healthcare, knowledgeable society, and Education 5.0. Finally, a connection also existed between Society 5.0 and smart cities.

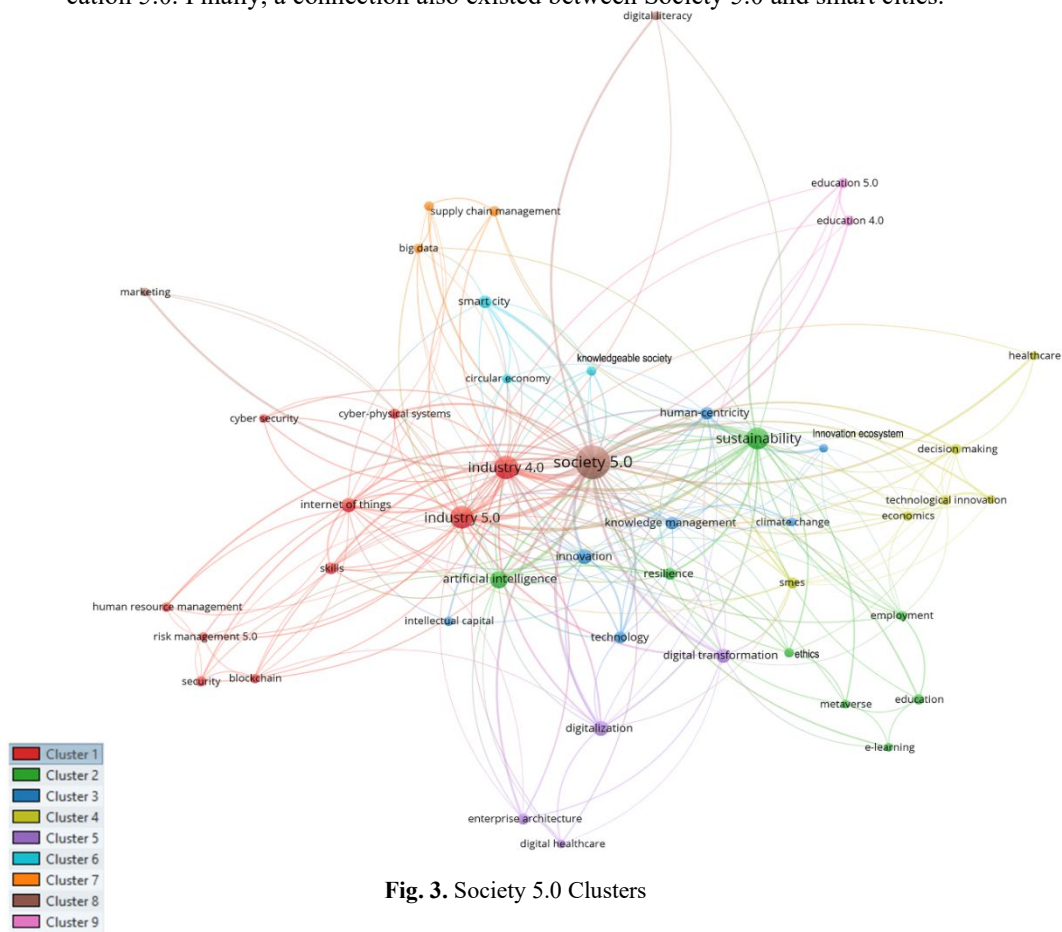


Fig. 3. Society 5.0 Clusters

Table 2. Society 5.0 Nodes Connection

Main Node (Cluster)	Connection With Cluster	Keywords (Frequency of Occurrence)
SMEs (8) Cluster 4	1	Industry 5.0 (65); Industry 4.0 (61); Internet of Things (15).
	2	Sustainability (55).
	3	Innovation (17).
	5	Digitalization (17); Digital Transformation (16).
	8	Society 5.0 (177).
Smart City (11) Cluster 6	1	Industry 5.0 (65); Industry 4.0 (61); Internet of Things (15).
	2	Sustainability (55).
	3	Innovation (17).
	7	Big Data (5).
	8	Society 5.0 (177).
Society 5.0 (177) Cluster 8	1	Industry 5.0 (65); Industry 4.0 (61); Internet of Things (15); Skills (9); Cyber-Physical Systems (7); Security (6); Blockchain (5); Human Resource Management (5); Cyber Security (4); Risk Management 5.0 (4).
	2	Sustainability (55); Resilience (10); Artificial Intelligence (28); Employment (5); Education (7); E-Learning (4).
	3	Innovation (17); Knowledge Management (12); Human-Centricity (12); Technology (10); Intellectual Capital (5); Innovation Ecosystem (4); Climate Change (4).
	4	Smes (8); Economics (5); Technological Innovation (5); Cognitive Mapping (4); Healthcare (4).
	5	Digitalization (17); Digital Transformation (16); Enterprise Architecture (8); Digital Healthcare (4).
	6	Smart City (11); Circular Economy (5); Knowledgeable Society (5).
	7	Big Data (5); Digital Twin (5).
	9	Education 5.0 (7); Education 4.0 (6).

4.3 Innovation 5.0 Clusters Analysis

The test was repeated with the same criteria. Out of 2071 keywords, only 40 met the criteria of appearing at least five times. The map in Figure 3 shows the development of six clusters representing important elements of Innovation 5.0, while Table 2 outlines the main relationships between nodes and keywords in the clusters.

Initially, keywords related to Society 5.0, smart cities, and SME's knowledge management were gathered into cluster 1 and connected to education, leadership, and innovation management keywords in cluster 4 through sustainable development goals keyword. The cluster analysis also indicated that the innovation keyword, along with entrepreneurship, creativity, management, resilience, human centricity, and social sustainability, are accumulated in one cluster. These findings suggest that the level of innovation within societies and organizations is closely tied to the caliber of individuals and their education within those societies [8] and that smart cities led by competent leaders are likely to exhibit higher levels of innovation [18], especially those who are looking for sustainable change [19].

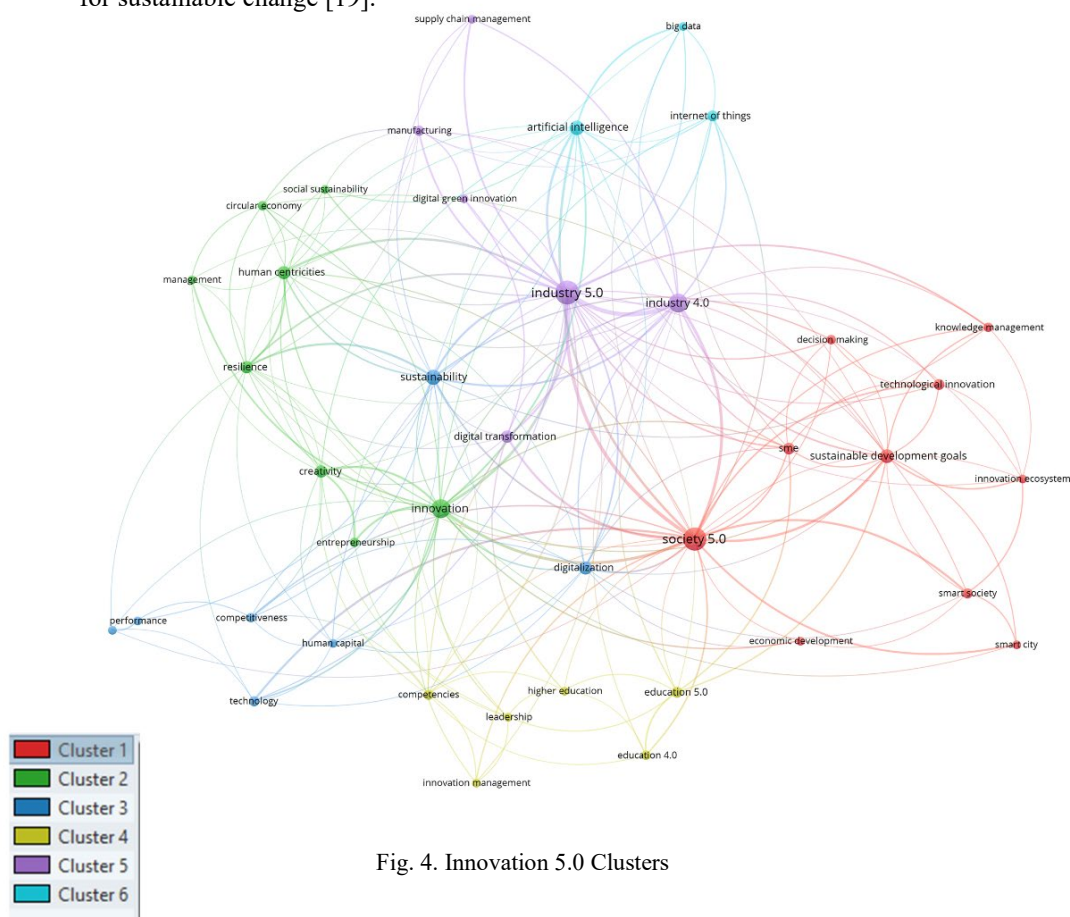


Fig. 4. Innovation 5.0 Clusters

Table 3. Innovation 5.0 Nodes Connection

Main Node (Cluster)	Connection With Cluster	Keywords (Frequency of Occurrence)
Society 5.0 (58) Cluster 1	2	Innovation (31); Human Centricities (12); Resilience (10).
	3	Digitalization (11); Technology (6); Competitiveness (5); Productivity (4).
	4	Education 5.0 (7); Competencies (6); Education 4.0 (5); Higher Education (4); Innovation Management (4).
	5	Industry 5.0 (63); Industry 4.0 (33); Digital Transformation (10).
Innovation (31) Cluster 2	6	Artificial Intelligence (15); Internet of Things (7); Big Data (4).
	1	Society 5.0 (58); Sustainable Development Goals (14); Sme (8); Smart City (4); Economic Development (4).
	3	Sustainability (18); Digitalization (11); Technology (6) Competitiveness (5); Productivity (4); Human Capital (4).
	4	Innovation Management (4); Leadership (4).
Sustainability (18) Cluster 3	5	Industry 5.0 (63); Industry 4.0 (33).
	6	Artificial Intelligence (15); Internet of Things (7); Big Data (4).
	1	Society 5.0 (58); Decision Making (5); Knowledge Management (5).
	2	Innovation (31); Human Centricities (12); Resilience (10); Creativity (9); Entrepreneurship (5); Circular Economy (5).
Education 5.0 (7) Cluster 4	4	Competencies (6); Leadership (4).
	5	Industry 5.0 (63); Industry 4.0 (33); Digital Transformation (10); Manufacturing (6); Supply Chain Management (4).
	6	Artificial Intelligence (15); Internet of Things (7).
	1	Society 5.0 (58); Sustainable Development Goals (14); SMEs (8).
Industry 5.0 (63) Cluster 5	5	Industry 5.0 (63); Industry 4.0 (33).
	1	Society 5.0 (58); Sustainable Development Goals (14); Sme (8); Technological Innovation (7); Smart Society (6); Knowledge Management (5); Decision Making (5); Innovation Ecosystem (4).
	2	Innovation (31); Human Centricities (12); Resilience (10); Creativity (9); Circular Economy (5); Management (4); Social Sustainability (4).
	3	Sustainability (18); Digitalization (11); Technology (6); Human Capital (4).
	4	Education 5.0 (7); Competencies (6); Innovation Management (4).
	6	Artificial Intelligence (15); Internet of Things (7); Big Data (4).

4.4 Connection between Industry 5.0, Society 5.0, and Innovation 5.0 Clusters

At the last stage, we combined the datasets of the three keywords Industry 5.0, Society 5.0, and Innovation 5.0 in one analysis to understand cluster connections. Out of 3826 keywords, 121 met the threshold of 4 minimum cooccurrences; the analyses shown in Fig. 5 indicated the existence of 8 connected clusters.

Industry 5.0, the main keyword of cluster 1, showed a connection with several keyword technologies within the same cluster and other clusters; for example, Industry 5.0 keyword indicated a connection with IOT, AI, blockchain, 5G, virtual reality, augmented reality, cyber-physical systems, cobots, and technology keywords in clusters 5, 2, and 4. Industry 5.0 also demonstrated a connection with various organizations and management keywords, including manufacturing, human-robot collaboration, supply chain management, and decision support systems within the same cluster, as well as with automation and the industrial revolution within Cluster 4. Additionally, the connection between the Industry 5.0 node and societal or human keywords, such as employment, higher education, education 5.0, human-centeredness, resilience, and decision-making, was also evident in other clusters. Moreover, the deducted clusters' main nodes, such as sustainability, sustainable development, innovation, smart cities, knowledge management, and digitalization, appeared to have a connection with the industry 5.0 keyword.

Smart city keywords mediated the relationship between Industry 4.0 and Industry 5.0—along with connected keywords—and Society 5.0 and sustainable development keywords of Cluster 2. The term "sustainable development" mediated the connection between smart city and each of the digital transformation keywords of cluster 8, knowledge management, students, transparency, and society 5.0 keywords of cluster 2, education and decision-making keywords of cluster 3, and sustainability keyword of cluster 2.

Nevertheless, the digitalization keyword from cluster 3, the automation and robots keywords from the same cluster, the business model and circular economy keywords from cluster 7, the education and job satisfaction keywords from cluster 3, and the logistics keywords from cluster 6 all played a mediating role in the relationship between smart cities and marketing.

Finally, the innovation keyword in cluster 6 demonstrated a relationship with leadership, education, and the industrial revolution. It also acted as a mediator between the business model and each of the industry 5.0 and sustainability keywords in clusters 1 and 2, respectively.

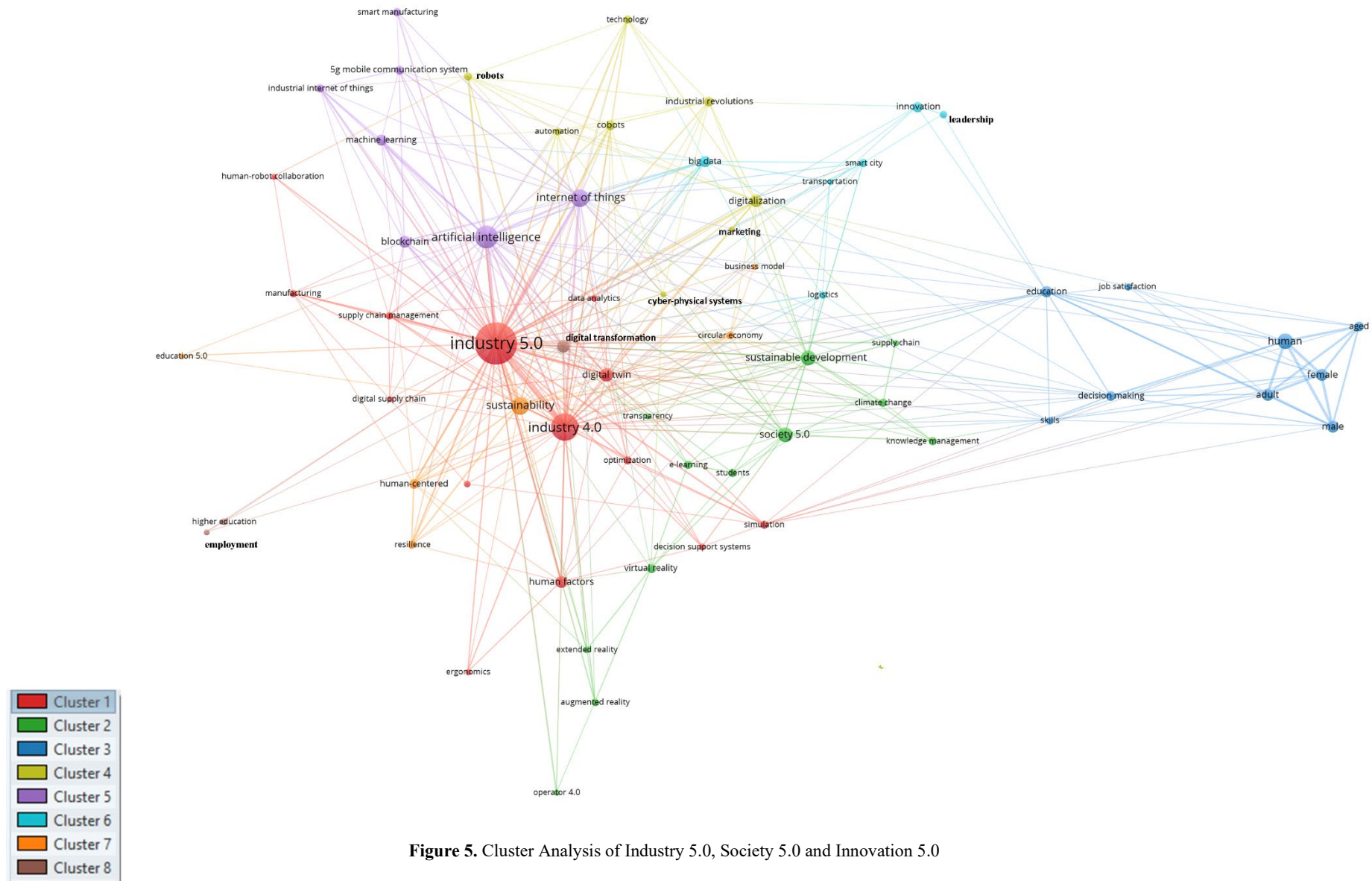


Figure 5. Cluster Analysis of Industry 5.0, Society 5.0 and Innovation 5.0

5 Discussion

Comprehending the interconnectedness of Industry 5.0 and Society 5.0 is essential for an effective implementation in organizations and management to sustain innovation. Industry 5.0 centers around the integration of machines and humans in the production and manufacturing process, with a particular emphasis on the significance of human creativity and abilities [14]. Society 5.0 utilizes technology to empower individuals, promote equality, and establish resilient communities that actively participate in business activities and organizations [20]. Innovation 5.0, within this framework, emphasizes the cultivation of an environment that promotes creativity and entrepreneurship. It aims to propel the advancement of novel technologies and solutions that tackle societal issues [8]. Based on these assumptions and the cluster analyses, we present the framework shown in Fig. 6, which looks at how these three ideas are connected to help us understand how they fit together and how they can work together to create a lasting and creative society in the future and for organizational activities.

Our framework consists of three main elements that lead to organizational innovation and triple bottom sustainability. The first element is Industry 5.0, which encompasses several components of advanced technologies (i.e., AI, IoT, extended reality, cobots, blockchain, and big data analytics) that are shaping the activities of the contemporary industry. With the existence of smart cities, Industry 5.0 technologies enable these cities to play a vital role in evolving business operations and creating Society 5.0. For instance, by utilizing data analytics and IoT services, cities and enterprises can improve energy efficiency, reduce waste, promote green technology solutions, optimize planning, transportation systems, and resource management [18]. Besides, Society 5.0 prospers as inhabitants need to acquire new soft skills like critical thinking, problem-solving, creativity, and emotional intelligence, as well as hard skills related to artificial intelligence, data analytics, and cyber security [2]. Thus, smart city evolution leads to advancement on an individual, societal, and organizational level. By integrating Industry 5.0 technology into Society 5.0 and smart cities, businesses can improve their operations across the entire value chain [21]. For instance, organizations can benefit from smart cities by attracting individuals who acquire new skills as a result of being citizens of these cities. These individuals can also develop intrapreneurship and entrepreneurial orientations to enhance their organizational activities or initiate new innovative ventures. Organizations must adapt their operations to integrate Industry 5.0 technologies and processes and Society 5.0 facilities and infrastructure in order to stay competitive and cater to the needs and preferences of their customers through personalized and innovative solutions based on optimal decision-making techniques, tailored marketing activities, and a digitized supply chain.

Nevertheless, Society 5.0 emphasizes the importance of collaboration, innovation, and empathy, which can significantly impact organizational culture and employee engagement. Companies that embrace these values are more likely to foster a sense of purpose and belonging among their employees, leading to higher levels of motivation,

productivity, and innovation. Incorporating Industry 5.0 and Society 5.0 principles into their operations allows organizations to adapt to the changing landscape of business and technology. By leveraging these synergies, companies can stay ahead of the curve, drive Innovation 5.0 within their industries, and foster triple bottom line sustainability [22].

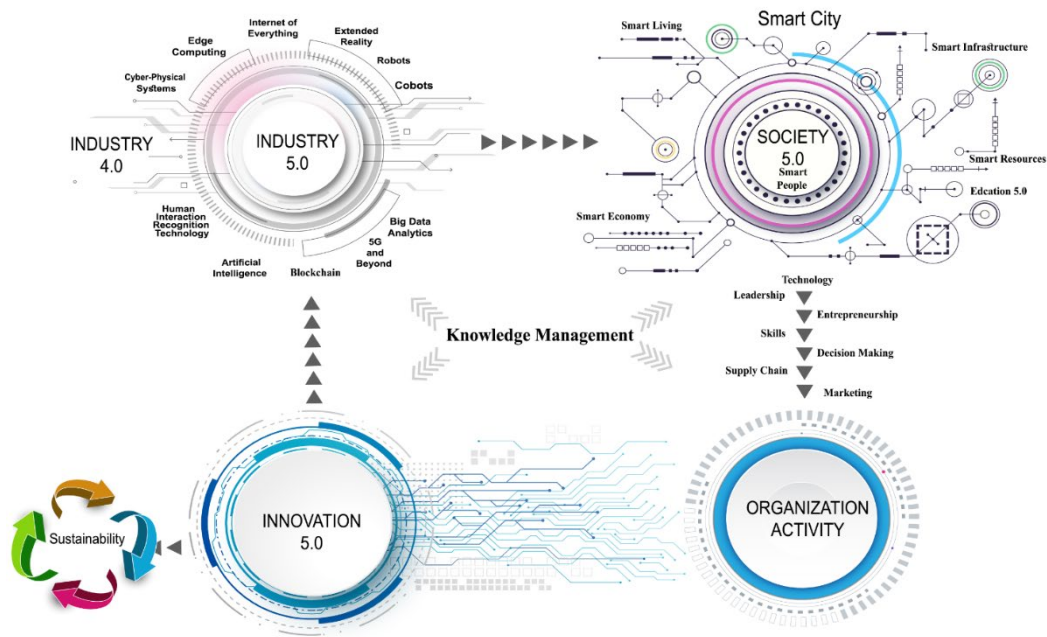


Figure 6. Organizational framework to foster innovation

6 Conclusion

This research enhances understanding of Industry 5.0, Society 5.0, and Innovation 5.0 in the context of business and management literature by offering insights on the published articles in the WOS and Scopus databases using a keyword analysis. The research also aimed to create a framework that aims to provide academics and practitioners with an initial view on the interaction of these concepts to yield an innovative business activity.

From an academic perspective, the framework suggests Industry 5.0 technologies facilitate the coexistence of smart cities and Society 5.0, advancing Innovation 5.0 activities by firms, entrepreneurs, governments, and policymakers. Practitioners should proactively find possible opportunities for early adoption and integration into business activities. Keeping up with current technology and industry trends is essential for organizations to effectively execute an Industry 5.0 transformation plan.

In order to seize the potential and tackle the challenges presented by these paradigms, businesses and policymakers must prioritize investing in infrastructure and fostering collaborations between enterprises and educational institutions to create training initiatives for individuals in the digital age. This will ensure that all societies progress simultaneously towards Society 5.0 and Innovation 5.0.

This study encompasses some limitations, as it only focused on business and management. It did not notice disciplines like engineering, computer science, and medicine. Besides, while WOS and Scopus are reputed databases, there are some useful publications available in unindexed journals and Google Scholar. Ignoring these sources might be considered a shortcoming of our study to some extent. However, the analysis provides valuable information for the academic community and offers guidance for future research. Future research could empirically examine Industry 5.0's enabling technologies, their impact on smart cities and Society 5.0, and whether smart cities mediate the relationship between Industry 5.0 and business activities.

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