Artificial Intelligence and Sustainable Supply Chain in Dairy Industry: A Systematic Review and Bibliometric Analysis

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ABSTRACT
Dairy industry needs an effective and efficient logistics system for managing supply chain across the chain. The main aim of this paper is the critically review the existing literature and analyse the sustainable supply chain practices with special reference to the dairy industry. This review identifies past and emerging concepts as well as methodologies in dairy supply chain. The objective of the present study is also to review how the modern technologies like artificial intelligence, Internet of Things, Block Chain are linked with the sustainability in the dairy supply chain, which ultimately impacting on the business performances. The study conducted systematic literature review on sustainable supply chain in dairy industry using PRISMA model based on 37 papers from the databases from 2012 to 2023. The study used published literature, peer reviewed journals, Industrial reports, official website etc. This analysis covers topics like most cited articles, co-citation analysis, bibliographic coupling. Based on the review of literatures, theoretical framework has been developed. The literature suggested that industry 4.0 through block chain platform has helped the industry in improving their supply chain performance. The study will be helpful in setting the future research directions for both the practitioners and academia in the area of AI applications for sustainable practises in Indian dairy Industry in order to improving supply chain and logistics and limit carbon emissions.
Key Words: Sustainable supply chain, Dairy Industry, Artificial intelligence, Smart Logistics, energy consumption, carbon emission.

1. INTRODUCTION

Global environmental pollution and wastage is one of the major issues, gripping the earth day by day, during the last few decades. While seeking the path to industrialization consistently, the natural resources are being overexploited and generated so much waste that its disposal became harmful to the environment and have guided new eras of research (Mara and Horan, 2003). Further, some of the emerging economies are going through the food shortage and food insecurity and food wastage has become big concern for them. Promoting sustainable manufacturing and expanding transport infrastructure in the "food business" is critical (Boruszko et al., 2018). A food supply chain connect millions of players, including farmers, businesses, governments, and other organizations, to address political and economic problems in local, national, or international contexts. The dairy-food supply chain is crucial for satisfying the population's nutritional requirement. In dairy industry, the product distribution, quality, timing, storing and transportation, key elements because of the low durability of dairy based products (Bhat et al., 2021). Further, during shipment and distribution, any dairy product faces a range of problems, such as managing the workforce, equipment damage, leakage, or spoilage. Hence, logistics plays a vital role in the design of dairy food supply chains. At the same time, logistics might also have an impact on an organization's ability to maintain its social, economic, and environmental sustainability through reduction in carbon dioxide emissions, food poverty, and waste. In recent times in sustainability in the food supply chain has gained significant attention from researchers. In order to improve the sustainability in milk supply chain, corporations have started concentrating upon labeling connected to food miles, which enables food managers to access the carbon footprint and ecological implications of the production and distribution practices (Pimentel et al., 2022). The major areas over which experts focuses on include scheduling, routing, and delivery, as well as environmental issues, monetary issues, social issues, the availability of vehicles, and communication between suppliers and recipients. To enable businesses to further develop their operating regions, the dairy industry requires air-conditioned or insulated transporters for the distribution of milk and related products (Sinha and Mishra, 2023). Value stream mapping plays a significant role in identifying waste in dairy supply chain (Kumar and Shankar, 2022). Many organizations in the dairy industry do not use environmentally sustainable refrigerants in their transportation units or cold storage facilities, which is a serious problem to sustainability of the environment (Sinha and Mishra, 2023). Further, due to poor transportation, chilling facilities require to store chilled milk for four to five days and the cost increases and lowering the profit margin which results have made the problem worse by rising oil prices. As ecological sustainability is gaining momentum for the last few years, the green supply chain management has become very significant in today's business scenario (Tripathy and Oberoi, 2025).

1.2. Evolution of AI in Sustainability

Experts have suggested an urgent need to address the growing global issues of environmental degradation, climate change, resource depletion, and social injustice. As a guiding principle, sustainability urges us to meet our demands today without jeopardizing the ability of future generations to meet theirs. Increasingly, artificial intelligence (AI) is playing a key role in promoting sustainable development and resolving these significant issues around the world (Nishnat et al., 2020). Researchers started to realize that AI's capability to research big datasets and forecast consequences will be used to clear up challenging ecological and societal troubles including predicting climate patterns, optimizing energy use, and better useful resource control (Smith et al., 2020). Climate change is one of the foremost important sustainability issues. AI has proven to be a useful tool for anticipating and mitigating the risks associated with climate change. Device learning algorithms analyze large datasets from satellites, climate stations, and environmental sensors to tune and respond to changes in the environment in real time. (Gandomi, 2015). This aids in disaster response, early warning systems, and the development of sustainable climate policies.

Sustainability depends on the wise management of resources including water, electricity, and raw materials. While smart grids use artificial intelligence (AI) to balance power supply and demand, reducing waste and dependency on non-renewable resources of strength, businesses have effectively used AI-based models for the prediction of water quality, the detection of pipeline leaks, and the extra powerful control of water treatment techniques (Nguyen et al., 2019). AI-based models aid in the prediction of water quality, the detection of pipeline leaks, and the more effective management of water treatment procedures (Smith, 2020).

The production of food is changing due to AI technology, which includes precision farming therefore, Sustainable agriculture is essential to meeting growing demand while preserving land and resources as the world's population continues to rise (Castelli et al., 2019). AI-powered technologies have helped the farmers in making data-driven decisions regarding planting, irrigation, and pest management, decreasing waste and environmental impact (Talaviya et al., 2020).

Machine learning algorithms are used to track species in danger, detect smuggling behavioral patterns, and study behavior of animals (Shivaprakash et al., 2022). Drones and AI-powered cameras make wildlife observation more effective and non-invasive (Shivaprakash et al., 2022). Therefore, These technologies have helped to conserve biodiversity and safeguard ecosystems.

Artificial intelligence (AI) technologies are becoming more and more capable of positively impacting sustainability. AI-powered circular economies offer a lot of capacity since they successfully reuse and recycle objects and resources (Breidt et al., 2018). AI may also play an important role in improving social and environmental sustainability by addressing issues like ethical labor practices social equality, optimal consumption, and a sustainable supply chain (Nishant et al., 2020).

1.3. Industry 4.0 and Dairy Industry

It is anticipated that Industry 4.0 will have a significant impact on enterprise fashions, strategies, and delivery chains to automate supply chain management, reduce costs, and improve performance. Owing to transportation problems, items can occasionally be delivered late or arrive to customers with diminished quality. Industry 4.0 has the potential to advance logistical methods, leading to more effective operational and revenue planning. Over the past few decades, the effects of Industry 4.0 technology have revolutionized the manufacturing industry and produced economies of value creation. Profitability, rapid sales and production, higher productivity and quality, and enhanced company efficiency are some of the benefits of Industry 4.0 for organizations. There is rise in global competitiveness in the area of Internet of Things (IOT), Cyber-Physical Systems (CPS), Machine Learning (ML), Artificial Intelligence (AI), Block chain Technology, self-driving robots, and additive manufacturing (Mubarik et al., 2023). These are facilitating production line to integrate with industry 4.0 in warehouses, real-time tracking of items (quality, availability, and location) across the chain along with warehouses located far from the plant, and thus helping in making the appropriate decisions.

2. PROBLEM STATEMENT

The dairy industry lacks implementation of Industry 4.0 like artificial intelligence, block chain etc. for validating the correct information of food products on real time basis. A significant amount of waste generation across the dairy chain coupled with the milk of inconsistent quality and quantity for many small farmers, timely procurement, storage, and transportation of milk products throughout the chain are key major challenges which dairy industry are facing. The co-operatives are suffering from significant challenges in the areas of managing people, short shelf life, high food losses and wastage, and high greenhouse gas emissions. Poor transportation infrastructure raises the inventory cost as chilling (refrigeration) facilities require store chilled milk/dairy for a longer period due to the lack of transport or faster mode of transport. This result with the increased cost overall and lowered profit margin Further, the significance of AI has been observed improving communication across the chain through sharing real time data in various industries. Therefore, it is imperative to understand the past and emerging practices of managing supply chain in dairy industry, especially, in the context, of achieving social, economic, and environmental performance (Leung et al., 2023). It also important to also examine how the adoption of modern technologies, with advent of Industry 4.0, contributing to the farmers, manufacturers and logistics partners in managing the supply chain right from the demand forecasting, order processing, distribution across the network, storage and finally to the consumer. There is a need to examine the linkage of adoption of modern technologies like AI, block chain, etc. with supply chain performance on social, economic, and environmental dimensions.

3. PURPOSE OF STUDY

There are four main objectives of the study

- To investigate the emerging concepts and application of supply chain in dairy industry.
- To study the application of the integration of modern technology like AI, IoT, and Block Chain and Sustainable supply chain management.
- To conceptualize the relationship among modern technologies in supply chain and sustainability with respect to dairy industry.
- To find the themes for the future research scope in the field of Sustainability integration with artificial intelligence with special preference to supply chain.

4. RESEARCH METHODOLOGY

4.1. Keyword Clustering:

In the initial phase of our research, we organized our search efforts around specific clusters of keywords. These clusters were chosen to encompass a range of topics related to sustainability and supply chain management. The clusters included "Sustainable development," "Smart supply chain," "Green operations/supply chain," "Sustainable Supply chain," and "Dairy supply chain." These clusters served as the foundation for our search strategy, helping us cast a wide net across the relevant literature.

4.2. Search Criteria:

We merged the primary clusters with additional terms like "logistics management," "Artificial intelligence," and "Industry 4.0" to make sure we got a wide variety of content. These extra keywords were chosen to highlight important and new developments in the industry. We were able to find variations of these terms by using the asterisk (*) wildcard character, which expanded the scope of search results. Thus our final cluster for the search is (("Sustainable development",” Smart supply chain”, "Green operations/supply chain" Sustainable Supply chain", "Dairy supply chain") AND ("logistics management*", "Artificial intelligence*" "Industry 4.0", , *"))

4.3. Volume of Results:

With 187 papers carrying out our search criteria in total, our search approach produced a sizable number of results. This extensive collection of materials comprises research papers, books, articles, and conference papers from various publishers.

4.4. Literature Review Selection:

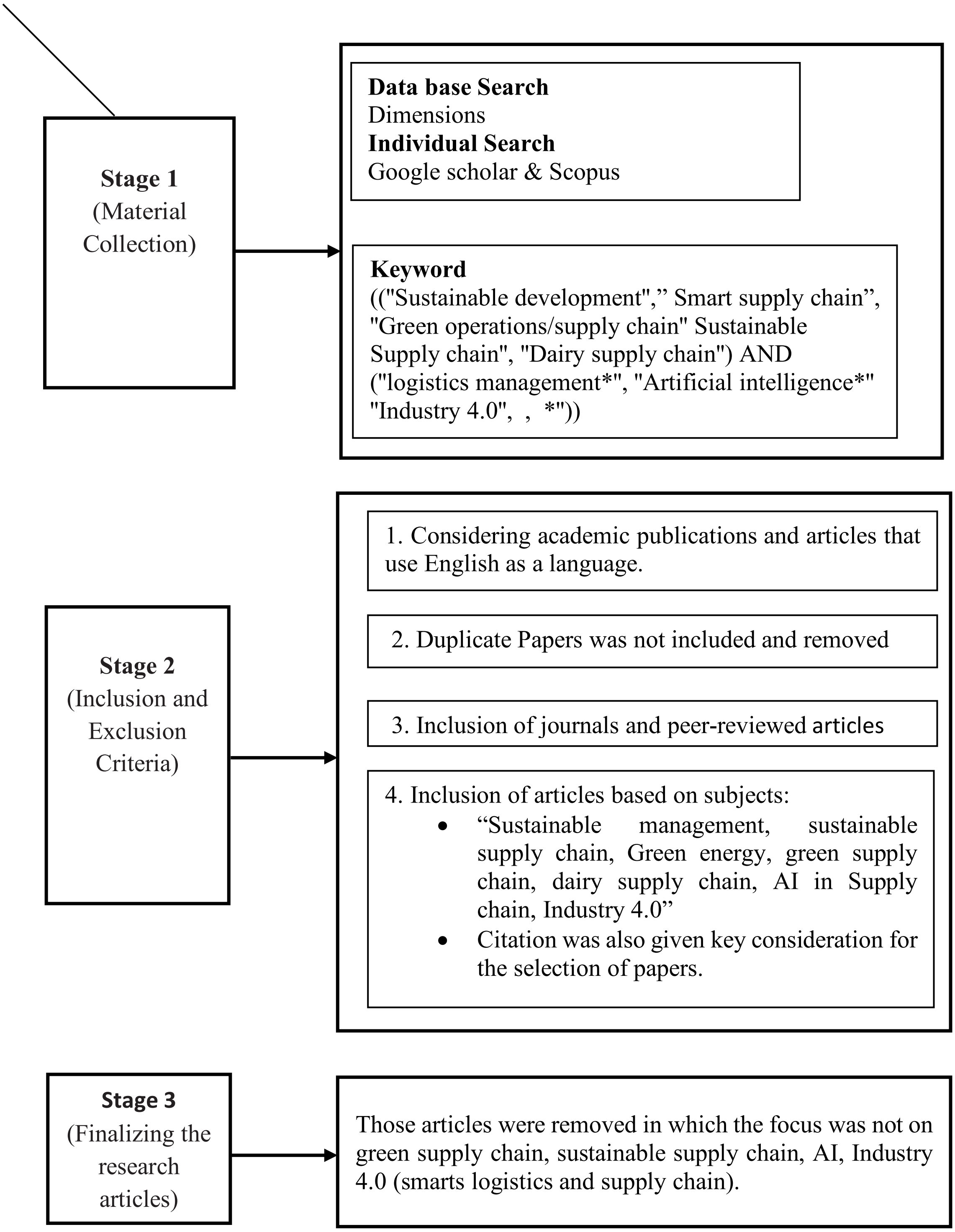
The content had to be carefully chosen in order to perform an exhaustive and insightful literature review. Out of the 187 articles in the original pool, we chose only 37 after a thorough and laborious review process. Their contributions to the topic, content quality, and relevance to our research objectives all played a role in this selection. Readers interested in our selection of literature can find a guide to the selected articles in Table 1.

4.5. Significance:

An important phase in the research process has been reached with the selection of these 37 articles. It demonstrates our dedication to offering an extensive but targeted analysis of the pertinent literature. These papers have been carefully selected to enhance the calibre and scope of our study, allowing us to provide valuable insights and analysis in our research report.

4.6. Bibliometric Analysis;

A software programme called VOSviewer was used to perform bibliometric analysis and network visualisation on 184 research articles, papers, and conference papers. Bibliometric analysis carried to explore different research themes and future research scope. Furthermore, six major themes have been identified. We included only papers which have English as a language and remove duplicate papers if any and also articles which were not focused on sustainable supply chain, artificial intelligence was removed. This research approach involved a structured and systematic search strategy that began with keyword clusters and extended to a thorough review of research articles. Figure 1 is shown below.



Source: Author’s compilation

Figure 1: Summary of the steps of SLR of Artificial intelligence integration with Sustainable supply chain.

Initially, we focused our search efforts on particular term clusters throughout the study phase. These clusters were selected to cover a variety of supply chain management and sustainability-related subjects."Sustainable development," "Smart supply chain," "Green operations/supply chain," "Sustainable Supply chain," as well as "Dairy supply chain" Our search method was based on these clusters, which enabled us to cover a large area of the relevant literature.

Table 1: Sustainable Supply chain Integrated with artificial intelligence 37 research Papers and articles.

Authors	**Year**	**Key Supply chain Functionalities**	**Other technologies Being Used**	**Research Type**
Sumarliah, Eli; Al-hakeem, Belal	2023	Traceability, Green supply chain	Big data analysis	Empirical, structural equation modelling
"Dwivedi, Ashish; Agrawal, Dindayal; Jha, Ajay; Mathiyazhagan, K."	2023	Intelligent manufacturing ,circular supply chain, Sustainability	Industry 5.0	Literature Review
Muhammad Azmat, Evanthia Thanou	2023	Transparency, Traceability	Block chain	Empirical
Gammelgaard, Britta; Nowicka, Katarzyna	2023	Traceability, Product Authenticity	Cloud computing	literature review and conceptual analysis
Richard G. Greenhill, Merette Khalil	2023	Accountability and Transparency	-	Experimental
Alexander Guda	2023	Transparency, Traceability, Decentralized	Digital interfaces, Industrial Internet of Things, Machine learning	Empirical
Rajeev Tiwari, Deepika Koundal, Shuchi Upadhyay	2023	Food Quality, Traceability, Authenticity	Image Based Computing	Empirical
Hosseinnia Shavaki, Fahimeh; Ebrahimi Ghahnavieh, Ali	2022	Sustainability, Traceability	Deep Learning algorithms	Literature Review
"Lei, Moyixi; Xu, Longqin; Liu, Tonglai; Liu, Shuangyin; Sun, Chuanheng"	2022	Food Quality, Traceability, Authenticity	Internet of Things, Privacy Preservation, Block chain	Literature Review
Nozari, Hamed; Ghahremani-Nahr, Javid; Fallah, Mohammad; Szmelter-jarosz, Agnieszka	2022	Traceability, Transparency	Internet of Things	Empirical and descriptive

"Lee, C. K. M.; Chung, S. Y"	2022	Traceability, Accountability, Traceability	Machine Learning, Big Data, the Internet of Things, and Cloud platforms	Literature Review
"Patidar, Akshay; Sharma, Monica; Agrawal, Rajeev; Sangwan, Kuldip Singh"	2022	Traceability, Sustainability	Industry 4.0	Literature Review
"Kumaresan Perumal, Chiranji Lal Chowdhary, Logan Chella"	2022	Traceability, Product Authenticity, Transparency	Machine learning, Block chain	Empirical
"Govindan, Kannan; Kannan, Devika; JÃ¸rgensen, Thomas BallegÃ¥rd; Nielsen, Tim Straarup"	2022	Transparency, Decentralized	Block chain, Industry 4.0	Empirical and Literature Review
"Tseng, Ming-Lang; Bui, Tat-Dat; Lim, Ming K.; Fujii, Minoru; Mishra, Umakanta"	2022	Sustainability, Traceability	Big data analysis	Empirical
"Sam Goundar, Archana Purwar, Ajmer Singh"	2022	Sustainability, Traceability, Quality	Big Data, Internet of Things	Empirical
"Kazancoglu, Yigit; Sagnak, Muhittin; Mangla, Sachin Kumar; Sezer, Muruvvet Deniz; Pala, Melisa Ozbiltekin"	2021	Product Quality, Authenticity, Automated Payment System	Machine learning, Optimization, Data mining, Cloud computing	Empirical
"Srinivas, Sharan; Rajendran, Suchithra; Ziegler, Hans"	2021	Traceability, Transparency	Advanced analytical,	Empirical
"Kuo, Tsai-Chi; Muniroh, Muniroh; Fau, Kristin Halisa"	2021	Quality management, Sustainability	RFID, QR codes	Empirical
"Toorajipour, Reza; Sohrabpour, Vahid; Nazarpour, Ali; Oghazi, Pejvak; Fischl, Maria"	2021	Food shortage detection, Traceability, Decentralized	Block chain, RFID, Machine learning	Literature Review
"Bhat, Showkat Ahmad; Huang, Nen-Fu; Sofi, Ishfaq Bashir; Sultan, Muhammad"	2021	Sustainability, Food security, Traceability	Block chain, Internet of things, RFID	Case study
"Udo Buscher, Rainer Lasch, Jörn Schönberger"	2021	Logistic Control, Waste management, Transparency	Internet of things, Big data Analytics	Literature Review
"Alexandre Dolgui, Alain Bernard, David Lemoine,	2021	Sustainability, Transparency,	Autonomous Robots, Advance	Empirical, Descriptive

Gregor von Cieminski, David Romero"		traceability, Logistic Management	modelling, Block chain	
"Sharan Srinivas, Suchithra Rajendran, Hans Ziegler"	2021	Product Quality, Authenticity, Accountability	Predictive and Prescriptive modelling	Empirical, Case study
"Turan Paksoy, Çiğdem Koçhan, Sadia Samar Ali"	2020	Production Quality, Sustainability	Internet of Things (IoT) and Cyber Physical Systems, Robotics, Cyber security, Data analytics, Block chain	Empirical, Descriptive
"Sachin Kumar Mangla, Mangey Ram"	2020	Sustainable Sourcing, Transparency, Traceability	Cloud computing, Internet of things, Block chain	Empirical, Descriptive
"Usha Ramanathan, Ramakrishnan Ramanathan"	2020	Transparency, Traceability, Quality Management	Mathematical Modelling, Statistical Analyses	Case study
"Shashi; Centobelli, Piera; Cerchione, Roberto; Ertz, Myriam"	2020	Demand chain Visibility	Internet of Things	Empirical
"Hassija, Vikas; Chamola, Vinay; Gupta, Vatsal; Jain, Sarthak; Guizani, Nadra"	2020	Connectivity, Transparency, Product Security	Block chain, Machine learning, Internet of Things	Empirical
"Lacy, Peter; Long, Jessica; Spindler, Wesley"	2020	Circular supply, Transparency, Accountability		Empirical, descriptive
"Florinda Matos, Valter Vairinhos, Isabel Salavisa, Leif Edvinsson, Maurizio Massar"	2020	Sustainability	Block chain, Internet of things	Empirical
"Mostafa Ezziyyani"	2020	Environmental Management, Transparency, Quality Management	Smart Supply Chain, Block chain, M-commerce, Internet of Things, Geo-information	Empirical, descriptive
Lee, In	2019	Transparency, Inter-connectivity	Internet of things	Empirical, descriptive

"Alon Shepon"	2018	Sustainability, Traceability	Big data analysis, Block chain, Internet of Things	Empirical
"Martin K. Starr, Sushil K. Gupta"	2017	Sustainability, Traceability, Audit ability		Empirical
"Lora M. Cecere, Charles W. Chase"	2012	Accountability and Transparency	Digital manufacturing	Empirical

Source: Author's Compilation

A total of 184 papers that met our search criteria were found using our search approach, The area of study had to be carefully chosen in order to perform an exhaustive and meaningful literature review, Among the 184 items in the original pool, we chose only 37 after a thorough and lengthy assessment procedure. This selection was made based on their relevance to our research objectives, the quality of their content, and their contributions to the topic. The selected articles are showcased in Table 1.

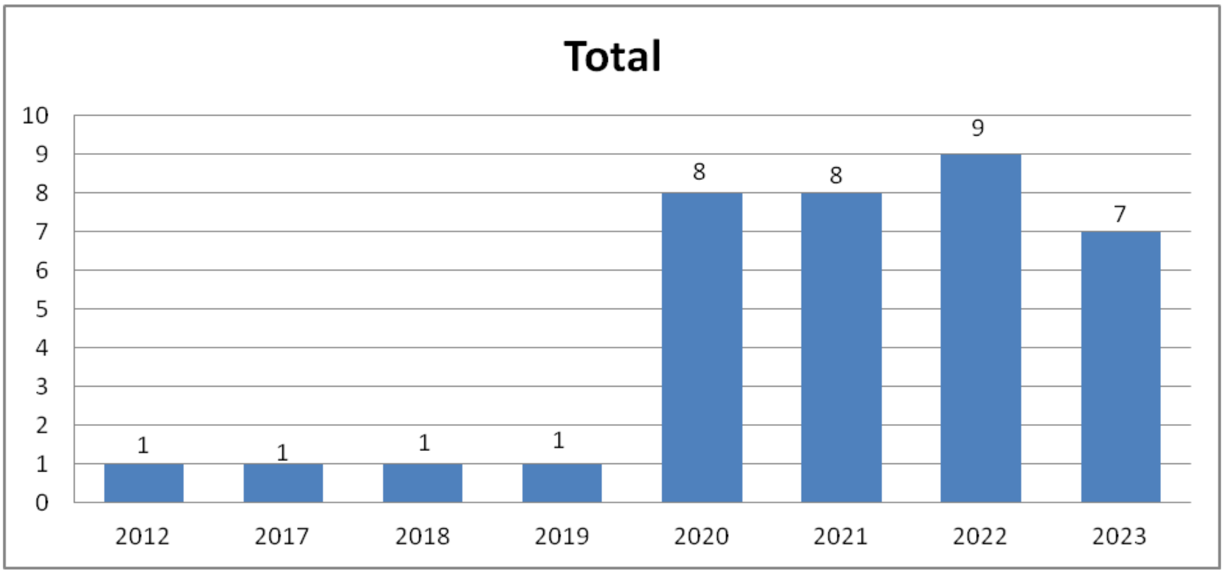


Figure 2: Year wise publications
Source: Author's Compilation

Figure 2 depicts the publication trend of research papers pertaining to the integration of Artificial Intelligence (AI) in Supply Chain Systems (SSCs) up to the year 2023. The study encompasses the entire publication period without any restrictions and takes into account the seminal paper authored by (Cecere et al., 2012), which explores the adaptation of AI in supply chain contexts. The visual representation in the figure illustrates the evolution and growth of literature in this field over the specified timeframe but therefore during the literature survey there were not even a single paper has found that focused on sustainable supply chain integrated with artificial intelligence with the view of dairy industry. Subsequent paragraph highlights

5. BIBLIOMETRIC AND NETWORK ANALYSIS

5.1. Co-authorship-Country Analysis;

The diagram depicts the network publications of articles among the 21 major countries since 2012 till 2023 (Figure 3).

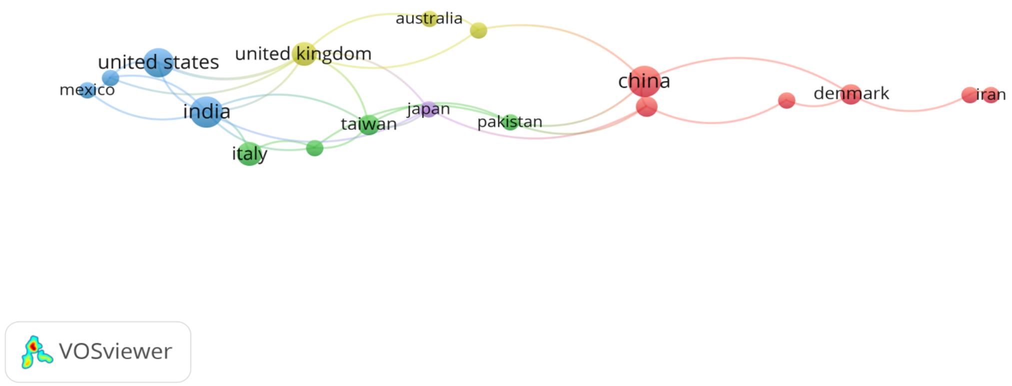


Figure 3: Cluster Visualization of "Co-authorship–countries relationship".

Source: Dimensions. Visualization: VOS viewer

The countries with the largest volume of published articles are represented by chart's larger bubbles. With seven publications each, China and India are in first place. With a total of four papers, the largest "yellow bubble" among them all represents the "United Kingdom", indicating its noteworthy scientific contributions to the incorporation of artificial intelligence into Sustainable Supply Chains (SSCs). In the figure above, the "U.S." is signified by a large "blue bubble," indicating a total of six articles published by the "North American country." Italy is next, with a medium-sized "green bubble," signifying a total of four documents, and Taiwan, Denmark, and Malaysia are last, with three published articles each. Five distinct clusters of countries can be observed in the network diagram, each denoted by a different colour (Figure 2). The size of a country's label and circle is determined by the number of publications from that country and the significance of each article. A larger country label and circle indicate higher publication numbers and article importance. This graphical representation enables a clear visualization of interactions among the five groups. Each group is identified by the size of the circle and a unique colour, representing their level of collaboration. The larger the circle, the stronger the collaboration and the greater the number of publications within the countries analyzed. However, the proximity between countries in the diagram doesn't necessarily reflect their geographical distance, but rather the extent of collaboration between them.

Proposition **1:** There is a Lack of comprehensive methodologies for evaluating sustainable suppliers using

Table 2 shows the ranking of the top 21 countries in terms of scientific contributions made to the subject of artificial intelligence-integrated Sustainable Supply Chains (SSC). The table presents data on the quantity of publications in each nation, the aggregate number of citations obtained by these articles, and the general pertinence of the correlated linkages. Based on the number of publications published, the nations are arranged in descending order.

Table 2: Relevant publication data in the top 21 Countries.

Number	Country	Documents	Citations	Total link strength
1	Australia	2	6	2
2	Brazil	2	22	0
3	Canada	2	149	4
4	China	7	52	4
5	Denmark	3	228	3
6	India	7	211	8
7	Iran	2	8	1
8	Italy	4	90	2
9	Japan	2	35	4
10	Malaysia	3	22	4
11	Mexico	2	15	2
12	Pakistan	2	69	4
13	Poland	2	7	2
14	Singapore	2	6	3
15	South Africa	2	6	4
16	Spain	2	4	0
17	Sweden	2	223	2
18	Taiwan	3	102	5
19	Turkey	2	124	0
20	United kingdom	4	135	8
21	United states	6	157	4

With the help of data by VOSviewer, the seven countries with the highest number of citations which were; the Denmark with 228 citations, Sweden with 223 citation, India with 211 citation, United States with 157 citation, Canada with 149 citation, United Kingdom with 135 citation, Turkey with 124 citation. Figure 4 is shown below.

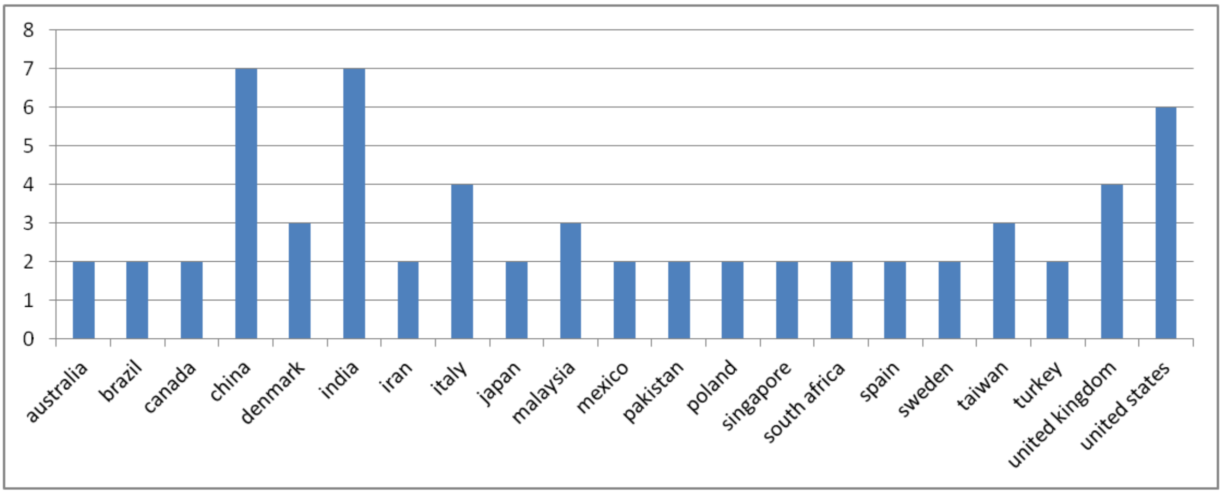


Figure 4: Country wise publication

Source; Author's Compilation

The trend of the publication of the papers on SSCs integrated with artificial intelligence with respect to different countries is shown in figure 5. Only countries with minimum two documents were selected for the analysis from 2012 to 2023 therefore India and china were focused to have highest number of documents 7 and on the other hand Denmark 228 and Sweden 223 has highest number of citations.

5.2. Co-citation Cited author.

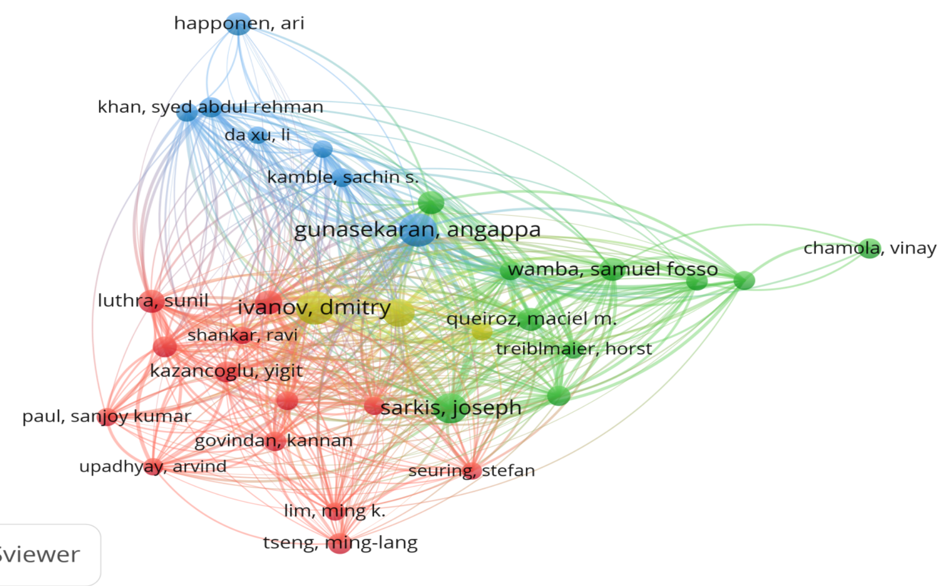


Figure 5: Cluster Visualisation of Co-citation Cited author.

Source: Visualisation: VOS viewer

Figure 5 presents a co-citation analysis of the 33 most influential authors and their interconnectedness in the field of sustainable supply chain integrated with artificial intelligence. The data covers publications between 2012 and 2023 and is sourced from the dimensions database. Prominent researchers, such as (gunasekaran, angappa), (ivanov, Dmitry), (dolgui, alexandre), and (mangla, sachin kumar), emerged as the most influential contributors based on their citation impact. Authors have minimum 15 number of citations have been selected in an attempt to remove the complexity in the connection diagram. Table 3 is shown below.

Table 3: Co-citation of Cited author

Number	Author	Citations	Total link strength
1	bag, surajit	16	622
2	chamola, vinay	20	97
3	choi, tsan-ming	26	1193
4	da xu, li	15	219
5	dolgui, alexandre	37	1164
6	govindan, kannan	19	611
7	(gunasekaran, angappa)	53	1591
8	happonen, ari	25	96
9	ivanov, Dmitry	52	1535
10	jabbour, charbel jose chiappetta	17	642
11	jayaraman, raja	18	583
12	kamble, sachin s.	18	641
13	kazancoglu, yigit	22	792
14	khan, syed abdul rehman	20	747
15	kouhizadeh, mahtab	20	742
16	kumar, ajay	17	989
17	kumar, anil	21	785
18	lim, ming k.	16	493
19	luthra, sunil	25	821
20	mangla, sachin kumar	27	999
21	paul, sanjoy kumar	16	397
22	queiroz, maciel m.	25	991
23	raut, rakesh d.	15	573
24	salah, khaled	17	538
25	sarkis, joseph	42	1524
26	seuring, Stefan	15	486
27	shankar, ravi	15	440
28	sokolov, boris	16	565
29	treiblmaier, horst	16	633
30	tseng, ming-lang	22	299
31	upadhyay, arvind	15	495
32	wamba, samuel fosso	26	1045
33	yu, zhang	17	690

However, the analysis reveals that American scholars wield greater influence in this domain compared to their productivity levels. This observation can be attributed to their publications being frequently featured in top-tier journals, garnering heightened attention from the scientific community. This finding aligns logically with the notion that higher citation impact is often associated with publications in esteemed academic outlets.

The analyzed co-citation network reveals four distinct clusters: the first (Red), second (Green), third (Blue), and fourth (Yellow) clusters. Within each cluster, prominent authors and their respective strength links, denoting the intensity of connections, are observed.
In the first cluster, Mangla Sachin Kumar emerges as the most influential author with a remarkable strength link of 999, and his works have been cited 27 times.
In the second cluster, Joseph Sarkis was observed as the most influential author,with a significant strength link of 1524, and his publications have been cited 42 times.
In the third cluster, Angappa Gunasekaran demonstrates substantial influence, boasting a robust strength link of 1591, and his works have garnered 53 citations.
Finally, within the fourth cluster, Dmitry Ivanov was identified as the most influential author, with the strength link of 1535, and his contributions have been cited 52 times.
These findings underscore the impact and recognition these authors have received within their respective clusters, highlighting their scholarly influence and citation impact in the field of sustainable supply chain integrated with artificial intelligence.
***Proposition* 2**: limited understanding of how AI-driven decisions align with ethical SSCM practices.

5.3. Bibliographic coupling- Documents

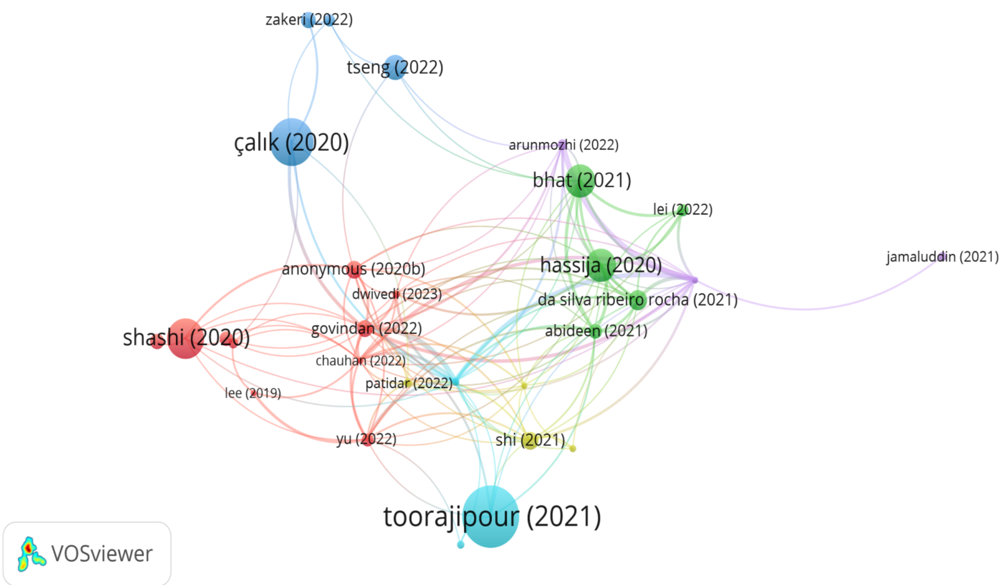


Figure 6: Cluster Visualisation of bibliographic coupling- Documents
Source: Visualisation: VOS viewer
Figure 6 presents a co-citation analysis of the 80 most influential authors and their interconnectedness in the field of sustainable supply chain integrated with artificial intelligence. The data covers publications between 2012 and 2023 and is sourced from the dimensions database. The visualization come up with six different clusters shown in figure 6.
In the first cluster (Red in Figure 6) the most important contribution by Shashi et al., (2020) which majorly focused on agile supply chain management and role of digital transformation improving the organization supply chain and give an edge over competition. Therefore it has a good strength link (10) and it is also cited in (90) documents.

In the second cluster (Green in Figure 6) the most important contribution by Hassija et al., (2020) which discussed the Supply chain's security-critical application areas and presents a detailed survey of the security issues in the existing supply chain architecture and propose the implementation of artificial intelligence to get the perfect supply chain environment (Hassija et al., 2020). Therefore, it produced the highest cited article in cluster 2 with citation score of 61 and the strength link of 27. Table 4 is shown below.

Table 4: Bibliometric coupling; Documents (min.2)

Number	Document	Citations	Total link strength
1	hosseinnia shavaki (2022)	2	13
2	manzoor (2022)	2	82
3	lei (2022)	8	18
4	chauhan (2022)	2	40
5	nozari (2022)	6	6
6	abideen (2021)	12	35
7	patidar (2022)	5	13
8	núñez-merino (2022)	4	71
9	çalık (2020)	124	16
10	shi (2021)	17	23
11	lee (2019)	2	9
12	okwu (2022)	4	3
13	yu (2022)	10	31
14	arunmozhi (2022)	6	37
15	anonymous (2020a)	10	0
16	dwivedi (2023)	4	20
17	govindan (2022)	16	66
18	anonymous (2020b)	17	22
19	kuo (2021)	8	9
20	bhat (2021)	59	32
21	da silva ribeiro rocha (2021)	22	34
22	toorajipour (2021)	211	11
23	anonymous (2020c)	2	0
24	jamaluddin (2021)	5	2
25	tseng (2022)	35	4
26	zakeri (2022)	14	9
27	anonymous (2020d)	49	0
28	anonymous (2022a)	3	0
29	siagian (2022)	3	5
30	anonymous (2023)	2	0
31	shashi (2020)	90	10
32	anonymous (2021a)	9	0
33	anonymous (2021b)	2	0
34	anonymous (2021c)	6	0
35	anonymous (2022b)	2	0
36	anonymous (2019a)	7	0

37	hassija (2020)	61	27
38	anonymous (2019b)	16	0
39	anonymous (2020e)	2	0
40	anonymous (2021d)	3	0
41	lacy (2020)	90	0
42	anonymous (2018a)	7	0
43	anonymous (2021e)	3	0
44	anonymous (2021f)	2	0
45	anonymous (2021g)	3	0
46	anonymous (2021h)	2	0
47	misra (2021)	12	5
48	anonymous (2018b)	3	0
49	anonymous (2022c)	4	0
50	anonymous (2017a)	19	0
51	anonymous (2020f)	6	0
52	anonymous (2019c)	7	0
53	anonymous (2022d)	2	0
54	anonymous (2021i)	14	0
55	rajagopal (2020)	13	1
56	anonymous (2022e)	2	0
57	anonymous (2021j)	3	0
58	anonymous (2020g)	12	0
59	anonymous (2022f)	4	0
60	anonymous (2019d)	3	0
61	anonymous (2022g)	4	0
62	anonymous (2021k)	2	0
63	anonymous (2020h)	11	0
64	anonymous (2020i)	4	0
65	anonymous (2021l)	2	0
66	anonymous (2021m)	26	0
67	anonymous (2018c)	3	0
68	anonymous (2017b)	7	0
69	anonymous (2022h)	2	0
70	anonymous (2022i)	5	0
71	anonymous (2020j)	4	0
72	anonymous (2019e)	8	0
73	anonymous (2021n)	2	0
74	anonymous (2019f)	35	0
75	anonymous (2014)	6	0
76	anonymous (2022j)	2	0
77	anonymous (2022k)	2	0
78	anonymous (2020k)	19	0
79	anonymous (2012)	32	0
80	anonymous (2018d)	5	0

The most significant contribution to the third cluster blue in Figure 6 came from (Çalık 2020), who suggested creating a new group decision-making method based on Industry 4.0 elements for choosing the best green supplier through the integration of TOPSIS and AHP procedures in a Pythagorean fuzzy environment. Therefore it produced the highest cited article in cluster 3 with the citation score of 124 and holds the strength link of 16.
In the fourth cluster (Yellow in Figure 6) the most important contribution by Shi et al., (2021) which discussed the consideration of supply chain disruptions and 3Rs in the supply chain is proposed. This paper discussed the vulnerability of the global supply chain and role of modern technology in response to improve the process. Therefore it produced the highest cited article in cluster 3 which is 17 and holds the strength link of 23.
In the fifth cluster (purple, labelled in Figure 6.) the most cited paper is (Arunmozhi et al,. 2022) This study examines the relationship between blockchain-based smart contracts and artificial intelligence (AI) can enhance sustainable supply chain operations and this paper has received 6 citations and strength link of 37.
In the last and sixth cluster (light blue in Figure 6.) the most important contribution is made by (toorajipour et al,. 2021) and this study aimed to determine the current and potential AI techniques that could enhance both the study and practice of SCM. This paper also discussed the potential of Industry 4.0 in the supply chain management. This paper receives the higher number of citations in all the clusters with the citation score of 211 and shares a strength link of 11.
Therefore, Prominent researchers, such as (Toorajipour, 2021), (Çalık, 2020), (Shashi, 2020), and (Lacy, 2020), regarded as the most influential contributors based on their citation impact. This observation can be attributed to their publications being frequently featured in top-tier journals, garnering heightened attention from the scientific community. This finding aligns logically with the notion that higher citation impact is often associated with publications in esteemed academic outlets.
***Proposition* 2**: Scarcity of AI applications for real-time monitoring of environmental impacts in supply chains.

5.4. Bibliographic coupling – journals

Figure 7: Network of the bibliographic coupling – journals.
Source: Visualization: VOS viewer

Our analysis focused on scholarly publications and books that explore the integration of Sustainable Supply Chain with Artificial Intelligence up to the year 2023 and minimum number of documents of a source is 2. Among the journals studied, "Transportation Research Part E: Logistics and Transportation Review" exhibited the most robust link strength, boasting a value of 53. However, this journal only had two publications, which collectively received 22 citations. In comparison, the "Journal of Industrial Information Integration" displayed the second strongest link strength with a score of 43, yet it also had only two publications and did not receive any citations so far. Similarly, the "Journal of Enterprise Information Management" presented a strong link strength of 41, but its two publications only garnered one citation in total. Figure 7 is shown above.

Table 5: Bibliometric coupling; Journal wise publication;

Number	Source	Documents	citations	Total link Strength
1	Advances in intelligent systems and computing	6	52	0
2	Computers & industrial engineering	2	14	24
3	Ifip advances in information and communication technology	9	27	0
4	International series in operations research & management science	3	1	0
5	Journal of enterprise information management	2	1	41
6	Journal of industrial information integration	2	0	43
7	Lecture notes in civil engineering	2	1	0
8	Lecture notes in mechanical engineering	5	9	0
9	Lecture notes in networks and systems	9	6	0
10	Lecture notes on data engineering and communications technologies	3	0	0
11	Processes	2	10	23
12	Springer proceedings in mathematics & statistics	2	4	0
13	Studies in computational intelligence	2	8	0
14	Studies in systems, decision and control	2	2	0
15	Trade policy reviews	2	0	0
16	Transportation research part e logistics and transportation review	2	22	53

On the contrary, the "Advances in Intelligent Systems and Computing" journal stood out in terms of quantity, having the highest number of documents, totaling six publications, and also received the highest number of citations, with a count of 52. Additionally, the "IFIP Advances in Information and Communication Technology" journal had the highest number of documents, nine publications, and ranked second in terms of citations received. Figure 8 is shown below.

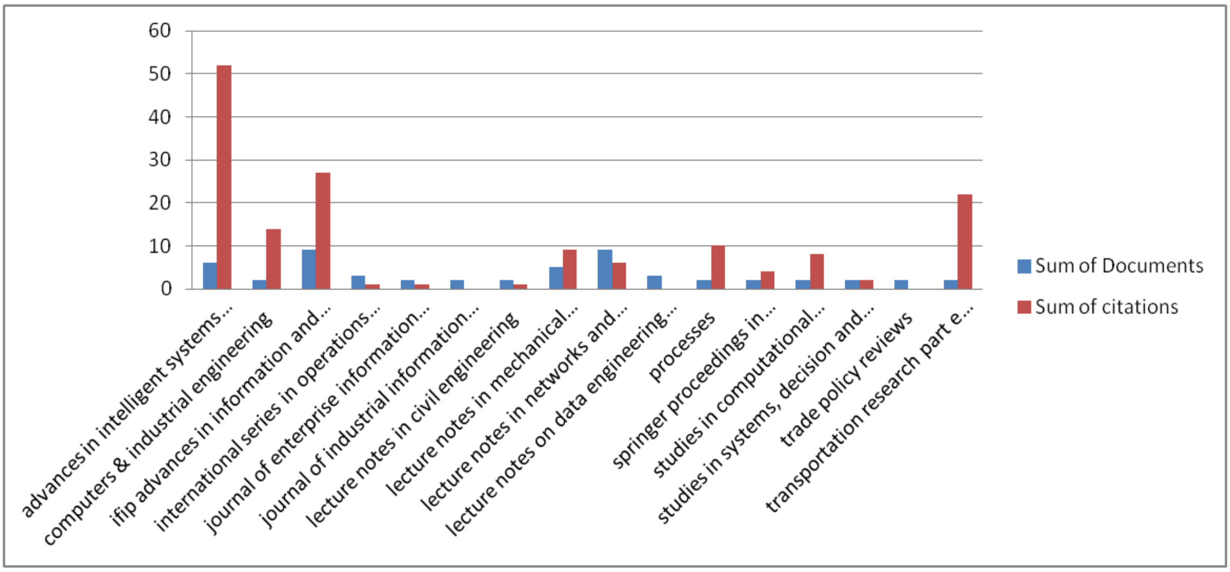


Figure 8: Journal wise publication
Source: Author's compilation

In light of these findings, it is evident that while certain journals have strong link strengths, the quantity and impact of publications, as measured by citations, varied among the studied journals.

Proposition **3:** Insufficient research on protecting sensitive SSCM data in AI-driven processes

5.5. Thematic Cluster and Analysis

The present study, the Vos-viewer tool was also employed to construct a thematic map utilizing co-occurrence keywords. The key words were searched in the dimension database both the title and abstract fields were utilized to extract these keywords and delineate emerging themes. To ensure robustness, our criteria dictated a minimum occurrence of 10 terms per keyword, yielding a total of 162 key terms. To refine the selection, we assigned relevance scores to each term. Subsequently, we opted for a default approach, choosing the top 60% most relevant terms, resulting in a final set of 97 terms. Table 5 reflects all the 97 key terms.

Table 6: Total of key words identified

Number	Term	Occurrences	relevance score
1	Academia	12	0.942
2	Academician	11	0.7586
3	Adoption	20	1.1685
4	Advance	39	0.6119
5	Agriculture	31	0.6604
6	Analysis	43	0.8467
7	Apms	18	1.7379
8	Approach	57	0.7233
9	Architecture	23	1.0242
10	Area	69	1.071
11	Article	16	0.9644

12	Author	14	0.7589
13	big data	21	0.993
14	blockchain technology	18	0.9884
15	Business	38	0.8098
16	case study	32	0.653
17	Chapter	48	1.239
18	communication technology	13	0.8856
19	Company	34	0.725
20	computer science	13	0.7506
21	Conference	70	0.7257
22	Contribution	18	0.6172
23	Control	28	0.8209
24	Country	15	1.1866
25	Cps	13	1.6487
26	digital technology	15	1.1265
27	digital transformation	28	0.632
28	digital twin	15	1.5139
29	Effect	19	1.3671
30	Engineer	15	0.9214
31	Evolution	14	0.6911
32	Expert	21	0.5939
33	Firm	13	1.2485
34	Food	15	1.0177
35	Future	23	0.6539
36	Government	15	1.3853
37	Handbook	24	0.9891
38	Iiot	17	1.0353
39	Impact	38	1.0342
40	Importance	12	0.8914
41	India	24	1.4202
42	Information	26	0.8001
43	Innovation	40	0.6017
44	Insight	17	0.7192
45	Internet	60	0.9306
46	Iot	78	1.0493
47	literature	28	1.1683
48	Logistic	38	0.5472
49	manufacturing	56	0.8691
50	Need	19	1.2524
51	new technology	11	0.7492
52	operations management	20	0.7983
53	opportunity	19	0.636
54	optimization	32	1.2239

55	Order	15	0.4853
56	organization	19	1.1994
57	pandemic	16	1.1436
58	paradigm	22	0.638
59	Part	20	0.5061
60	Person	13	0.6483
61	perspective	24	0.8281
62	practice	33	1.0481
63	Privacy	23	1.3409
64	proceedings	17	1.2335
65	product	23	0.8722
66	production	57	0.5981
67	production management	23	1.6777
68	production management systems	16	1.7405
69	production planning	14	1.7845
70	production system	30	1.6498
71	professional	23	0.7407
72	Reader	21	0.666
73	regular session	68	1.6509
74	research	69	0.7591
75	researcher	55	0.6117
76	Review	38	1.2205
77	Robotic	11	0.7237
78	security	35	1.0024
79	september	15	1.7293
80	smart city	22	1.2055
81	smart manufacturing	17	1.5436
82	State	19	0.6945
83	Student	38	0.5941
84	Study	76	1.1992
85	submission	11	1.6831
86	sustainable development	20	1.2165
87	systematic literature review	11	1.1743
88	technique	45	0.7825
89	technology management	10	1.5334
90	Term	14	1.2626
91	Thing	53	0.9781
92	Time	15	0.8421
93	University	25	0.4559
94	Use	33	1.091
95	Way	14	1.1224
96	World	21	0.7365
97	Year	15	1.2081

In the very next stage, chosen terms were refined. This involved a rigorous evaluation process to filter out any less pertinent terms, allowing us to retain those with the most significant relevance scores. Table 6 reflects the analysed themes or key terms identified.

Table 7: Total number of key words after analysis

Number	Term	Occurrences	relevance Score
1	Advance	39	0.3345
2	Agriculture	31	0.848
3	Analysis	43	0.6601
4	Architecture	23	1.4492
5	big data	21	1.274
6	block chain technology	18	0.7564
7	communication technology	13	1.2225
8	computer science	13	1.3505
9	contribution	18	0.8236
10	Control	28	0.4372
11	Country	15	0.8578
12	digital technology	15	1.2838
13	digital transformation	28	0.2378
14	digital twin	15	0.8481
15	Evolution	14	1.0834
16	Food	15	0.8775
17	Iiot	17	1.2905
18	Impact	38	1.156
19	Information	26	0.9023
20	Innovation	40	1.0925
21	Internet	60	1.059
22	Iot	78	1.177
23	manufacturing	56	0.5083
24	new technology	11	1.8668
25	operations management	20	0.8001
26	Opportunity	19	0.6401
27	optimization	32	0.5858
28	Privacy	23	1.5149
29	Product	23	0.424
30	Production	57	0.347
31	production management	23	0.961
32	production management systems	16	0.9836
33	production planning	14	0.963
34	Robotic	11	0.3641
35	Security	35	1.1122
36	smart city	22	1.9221
37	smart manufacturing	17	0.9694

38	sustainable development	20	1.414
39	Technique	45	0.4438
40	technology management	10	3.542
41	Time	15	0.616

This assessment took into account the existing body of research as well as the frequency of appearance of each term. The meticulous nature of this procedure underscores the meticulous scholarly approach we adopted in delineating our research themes.

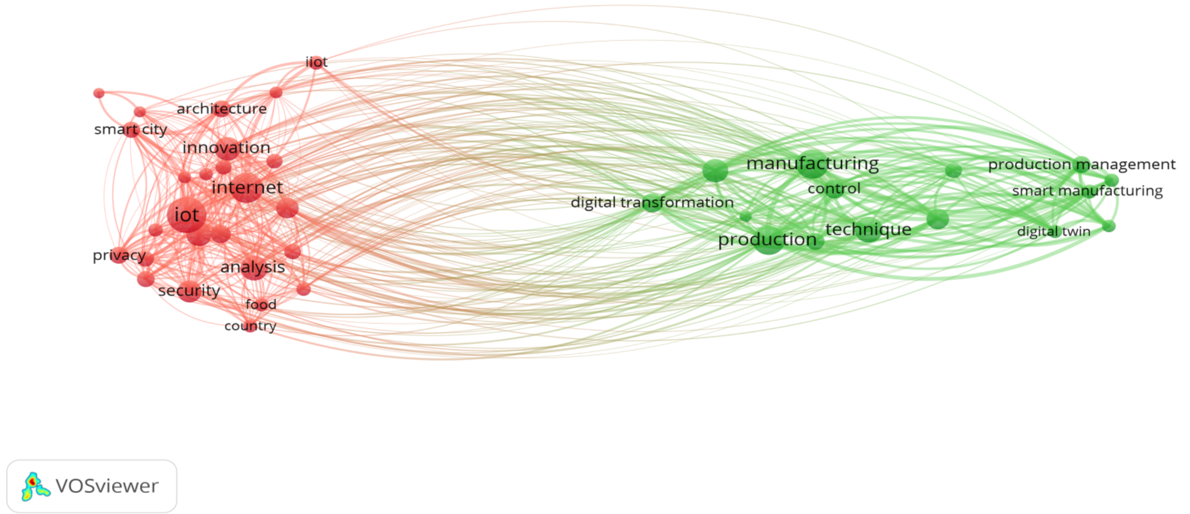


Figure 9: Map based on co-occurrence of key words; thematic analysis
Source: Visualization: VOSviewer

The maximum number of re-occurrence of word founds is IOT (Internet of things) which is occurred 78 times in the literature and followed by Internet which occurred 60 times in the literature and production is occurred overall 57 times in the literature thus these are the major key words which have developed through Vos-viewer and analysis which can be seen in figure 9

6. DISCUSSION

In today's supply chain management landscape, Artificial Intelligence (AI) is making a significant impact on sustainable practices. By using AI's analytical abilities, businesses can improve their operational efficiency, reduce waste, lower their carbon footprint, and make smarter decisions throughout their supply chain.

One key area where AI is transforming the field is deep leaning in the feel of supply chain management (Shavaki et al., 2022). Further, authors have discussed safety and quality of food through improving technology and this helps optimize inventory, which is crucial for sustainable supply chains. It prevents both overstocking and under stocking, reducing waste and ensuring resources are available as needed.

With the help of emerging technology such as Internet of things and neural networking demand patterns can be understand but according to (Nozari et al., 2022) safety and security of data is a major concern of supplier and distributor thus, it can be observed that data privacy is an integral part for trust building and lacking it this security system can hinder the process of digitization (Matos et al., 2020).

The integration of Industry 4.0's fundamental technologies into the supply chain fosters sustainability and transparency, facilitates informed decision-making, and eventually transforms the chain into a more intelligent and effective system (Patidar et al., 2023) but (Sinah et al., 2023) argued that lack of awareness and poor implementation process will lead to data breach and will increase the cost of operations and by developing a global framework will find the right balance between inventory volume and logistical needs, addressing inefficiencies that lead to resource waste. During literature survey we identified various component of supply chain that has been discussed as illustrated in Table 7.

Table 8: Different components Identified with description and benefits

Component	Description	Benefits
Sustainable procurement	AI assesses suppliers' sustainability practices	Ethical sourcing; Reduced environmental impact
Demand Forecasting	AI predicts demand patterns	Minimized waste; Efficient inventory control
Inventory Management	Real-time AI analysis for optimal stock levels	Reduced stockouts & excess inventory
Logistics Optimization	AI algorithms optimize transportation routes	Lower carbon footprint; Cost efficiency
Waste Reduction	AI identifies waste sources and trends	Waste reduction; Enhanced recycling

During the literature analysis it can be observed in Cluster Visualisation of Co-authorship–countries relationship that India and china have highest number of publication on the other hand, Denmark had only 3 publications but the citation is the highest which shows us the quality of work and significance needs to improve and there are only 21 countries that have made their contribution in the field of AI in sustainable supply chain.

In Cluster Visualisation of bibliographic coupling- Documents it is observed that major or most cited author's have focused more on supply chain management and role of digital transformation improving the organization supply chain and give an edge over competition which also replicates the trend of studies and focus of academicians. Further, it can also be observed that there are only few journals that have made their active participation in the field of artificial intelligence integration with sustainable supply chain and when it comes to dairy industry there are almost no empirical evidence is available.

Few papers, such as the work by Varriale et al. (2023), delve into the dairy industry, specifically addressing the integration of artificial intelligence within the cheese supply chain with a particular focus on cost analysis, predominantly covering the economic aspects of the supply chain. However, these studies tend to overlook various other factors. Similarly, Sinah et al. (2023) discuss the role of artificial intelligence in the dairy supply chain, relying solely on secondary databases for their analysis. Consequently, the dairy industry emerges as a emerging field that warrants in-depth exploration, especially in the context of the Indian dairy industry. Despite the dairy industry's substantial economic contributions, the emphasis on crafting sustainable supply chains seems to have been somewhat overlooked. Our comprehensive review of available literature, coupled with Bibliometric analysis, has yielded insights into potential research directions for future research which can be seen in figure10. Table 8 is shown above.

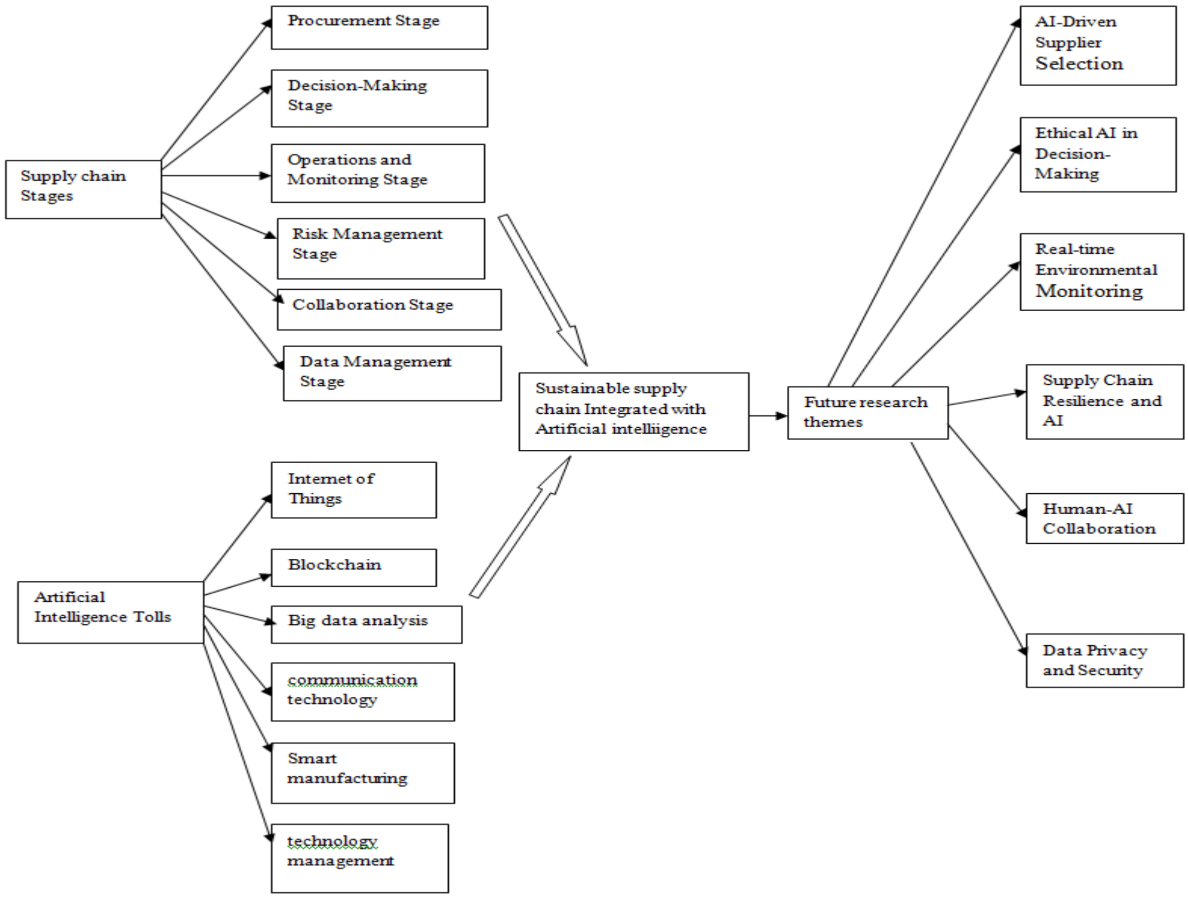


Figure 10: Future research themes identified
Source: Author's Compilation

In the beginning, thorough analysis of the existing literature was done to follow by identification of several common themes that appeared across various research papers and articles related to sustainability in supply chains at different stages. We also examined the role of artificial intelligence in supply chains. To assist in this process, we utilized VOSviewer software to analyze how frequently certain words appeared in the available literature. We specifically focused on words that occurred at least 10 times. After a detailed review of these keywords and the literature, we identified significant themes that have not been extensively explored and are in need of empirical evidence.
Therefore, integrating AI into sustainable supply chain practices leads to many improvements. AI supports data-driven decisions, predictive maintenance, collaboration, and transparent sustainability reporting. However, challenges like data privacy, biases in algorithms, and the need for skilled personnel must be addressed for AI to reach its full potential in sustainable supply chain management.

7. MANAGERIAL IMPLICATIONS;

The study offers significant implications for professionals, supply chain managers, and scholars actively engaged in the advancement of technology within the realm of sustainable supply chains. These implications can be summarized as follows:

1. Given that disruptive technologies such as AI, blockchain, and machine learning are relatively novel concepts within the domain of supply chain management, the study's findings underscore the importance of embracing contemporary trends in supply chain operations to promote sustainability through the adoption of modern technologies.
2. The study provides valuable insights by identifying limitations and gaps within supply chain practices, particularly in emerging economies like India. It suggests that addressing these gaps can be achieved through the development of real-time monitoring systems, which would be highly beneficial for supply chain managers.
3. This research serves as a valuable asset for organizational leaders, decision-makers, and policymakers, facilitating the development of proficient strategies and policies for the integration of AI technology. It emphasizes the required timeframes, infrastructure deficiencies, and the necessity for knowledge and training services to ensure the successful adoption of these technologies.
4. Furthermore, The findings of the study, which include an extensive evaluation of earlier studies, an examination of prominent researchers and major publications, and a discussion of potential directions for further research in this area, provide significant insights to the academic community.

8. CONCLUSION

This study aimed to acquire an understanding of the valuable development made in the area of artificial intelligence and sustainable supply chain integration using a systematic literature review of the existing literature.

Furthermore, Bibliometric analysis helps us in gaining an understanding of all the major contributions made by various nations and authors in this field. Our research revealed that India and China have been at the forefront in terms of generating substantial contributions, closely followed by the United States and the United Kingdom. In terms of citations for their articles, Denmark and Sweden emerged as the top two countries. When assessing the correlation between journals, our findings highlighted 16 journals as the most prolific in terms of publishing research on the integration of sustainable supply chains with artificial intelligence. Further, "Advances in Intelligent Systems and Computing" and "IFIP Advances in Information and Communication Technology" stood out as having the highest number of published documents. Through co-citation analysis of the 80 most influential authors and their interconnectedness in this field, it became evident that the work by Centobelli et al. (2020) made a substantial contribution. Their research predominantly focused on agile supply chain management and the role of digital transformation in enhancing organizational supply chains and competitive advantages. However, it is important to note that sustainability aspects were not thoroughly discussed. In light of the available literature, our analysis highlights a notable gap and future research themes through thematic analysis. While there has been significant attention on improving supply chains through digital transformation, there seems to be a comparative neglect of the crucial integration of green supply chain practices and the pursuit of sustainable supply chains through the application of artificial intelligence. This gap presents a promising avenue for future research endeavors in this field.

9. FUTURE SCOPE

This study focused exclusively on essential factors, utilizing data inputs spanning from 2012 to 2023. To enhance the credibility of the findings, it is recommended to undertake an empirical investigation with a more extensive sample size. Future research efforts may focus on AI-driven supplier selection (Banaeian et al., 2018), with a greater emphasis on the creation of an AI-based framework for supplier assessment. Table 9 is shown below.

Table 9: Future research themes with gaps identified.

Themes	Gap	Future Research Focus
AI-Driven Supplier Selection	Lack of comprehensive methodologies for evaluating sustainable suppliers using AI	Developing AI-based supplier assessment frameworks
Ethical AI in Decision-Making	Limited understanding of how AI-driven decisions align with ethical SSCM practices	Investigating AI algorithms for transparent and ethical decision-making
Real-time Environmental Monitoring	Scarcity of AI applications for real-time monitoring of environmental impacts in supply chains	Developing AI solutions for continuous environmental monitoring
Supply Chain Resilience and AI	Inadequate exploration of AI's role in enhancing SSCM resilience against disruptions	Examining AI-based strategies for supply chain risk management
Human-AI Collaboration	Limited insights into how humans and AI can collaborate effectively in SSCM	Analyzing human-AI interaction models for sustainable decision-making
Data Privacy and Security	Insufficient research on protecting sensitive SSCM data in AI-driven processes	Developing AI solutions for secure data handling in SSCM

Given the critical importance of decision-making processes in this environment, it is critical to investigate AI algorithms focused at supporting transparent and ethical decision-making procedures. Scarcity of AI applications for real-time monitoring of environmental impacts in supply chains. Developing AI solutions for continuous environmental monitoring can help in waste management. Severe data privacy issues, are critical problems with significant environmental repercussions. Further, we have only included articles with English as a language which may result in exclusion of various valuable articles thus, future research can be include other languages as well.

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