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Review article

IoT-based supply chain management: A systematic literature review

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ABSTRACT

Supply Chain Management (SCM) consists of handling and optimizing all the facets of the supply chain process of goods and services. Modern SCM is reaping the benefits from the emerging and growing Internet of Things (IoT) field. IoT technology can automate and digitalize the supply chain processes to get maximum operational efficiencies by reducing operating costs. The mass proliferation of IoT devices has revolutionized supply chains. IoT devices in the supply chain process track and trace shipments using the latest real-time monitoring technologies, including GPS. IoT devices are also used for asset management using NFC technology and RFID tags. Overall, IoT devices are used in almost every stage of the supply chain process. Research on IoT-based SCM is still in the growing phase. A lot of technical work is currently being published on IoT-based SCM, but a few Systematic Literature Reviews (SLRs) have been found for IoT-based SCM. The holistic view of IoT-based SCM with detailed analysis is still not reported in any review. This paper addresses this knowledge gap by presenting an SLR on IoT-based SCM with a detailed analysis of IoT-based SCM from 2018 to 2022. This review covers the aspects of IoT-based SCM, such as application domains, technologies, sensors, and devices used to implement IoT-based SCM systems. The SLR findings will assist future researchers and practitioners interested in IoT-based SCM by offering an in-depth study of the literature on IoT-based SCM, including helpful insights on challenges, benefits, and economic and business implications.

1. Introduction

Modern supply chains are holding innovative potential with the emergence and proliferation of IoT. Using IoT-enabled technologies, devices, and sensors helps optimize supply chain processes. Despite the growing popularity of IoT in Supply Chain Management (SCM), a holistic view of IoT-based SCM with detailed analysis is still not reported in any review. Therefore, this study addresses the knowledge gap by conducting an SLR within IoT-based SCM. This section discusses in detail the background of IoT and SCM and the significance of using IoT for SCM. A brief discussion of relevant literature reviews is also given in this section. This section also highlights the significant research contributions.

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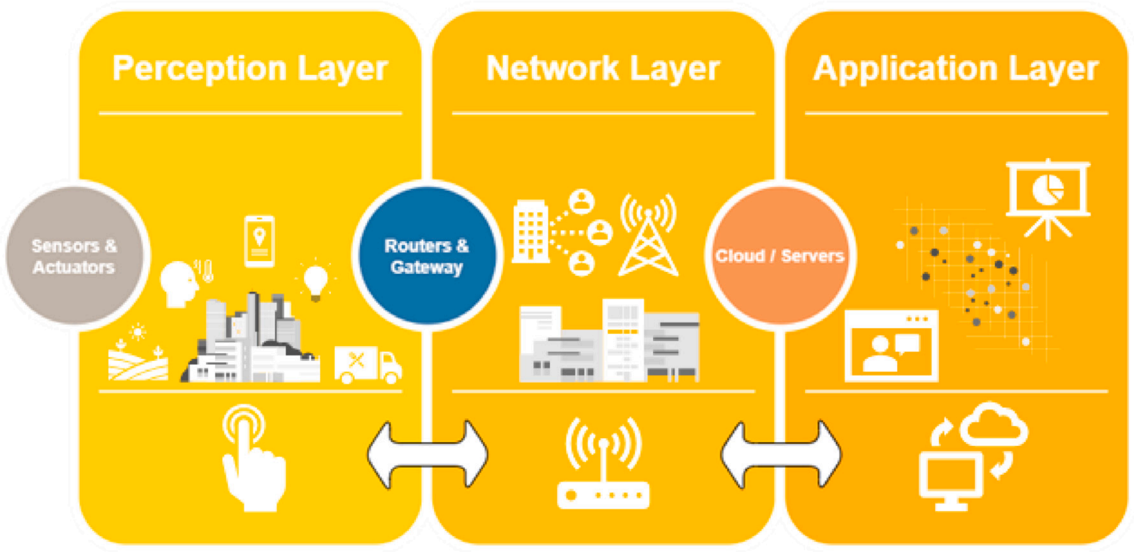

Fig. 1. IoT architecture.

1.1. Internet of Things (IoT)

IoT is the latest technology generally used in industry, and its applications add value to modern SCM. The term Internet of Things was initially coined in the 1990s. The main work was performed by the pioneer of IoT "Kevin Ashton" who was co-founder of the Auto-ID Laboratory at MIT. He introduced the term "The Internet of Things" to describe a system where the Internet is connected to the physical world via ubiquitous sensors, including RFID (Radio-frequency identification) [1]. IoT is used in several application areas, especially in business, due to ease of use in business operations [2]. The general architecture of IoT is composed of three layers, i.e., (1) the Perception layer, (2) the Network Layer, and (3) the Application Layer [3]. Fig. 1 illustrates the layered architecture of IoT.

1. Perception layer: The general architecture of IoT uses a bottom-up approach. The perception layer is the bottom layer. This layer is the physical layer of IoT architecture. The main purpose of this layer is to acquire data and physical parameters from the environment using different sensors, actuators, and other smart equipment.
2. Network Layer: The data collected from the perception layer is communicated and transmitted to other network devices, servers, and applications for further processing using the network layer.
3. Application Layer: This layer is the topmost layer of IoT architecture, and the role of this layer is to provide application-specific services to the end user. This layer helps to provide an intelligent IoT-based environment to end-users. This layer also contains programs and modules that businesses or enterprises use to view real-time data and make intelligent decisions for their business operations.

1.2. Supply Chain Management (SCM)

The Council of Supply Chain Management Professionals (CSCMP) has worked since 1963. It has provided a platform for the community and professionals actively contributing to the supply chain and logistics field. CSCMP has defined SCM as "supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. It also includes coordination and collaboration with channel partners, suppliers, intermediaries, third-party service providers, and customers. SCM integrates supply and demand management within and across companies" [4]. The process of SCM starts with the sourcing of raw materials. The supplier for the manufacturing of products collects the raw material. The manufacturers refine the raw material and provide finished products. After the manufacturing of products, the distribution of products takes place by wholesalers. The wholesalers sell these products to retailers, and consumers generally buy products from retailers. The general diagram for the SCM process is shown in Fig. 2.

1.3. Significance of using IoT for SCM

Traditional SCM process has several issues like overstocking, understocking, delays in the delivery of products, and problems in conveying real-time information. Effective and well-defined SCM processes drastically improve SCM operations and profitability. Due to technological advancements, businesses are adopting the latest technology for the SCM process. With the emergence of IoT,

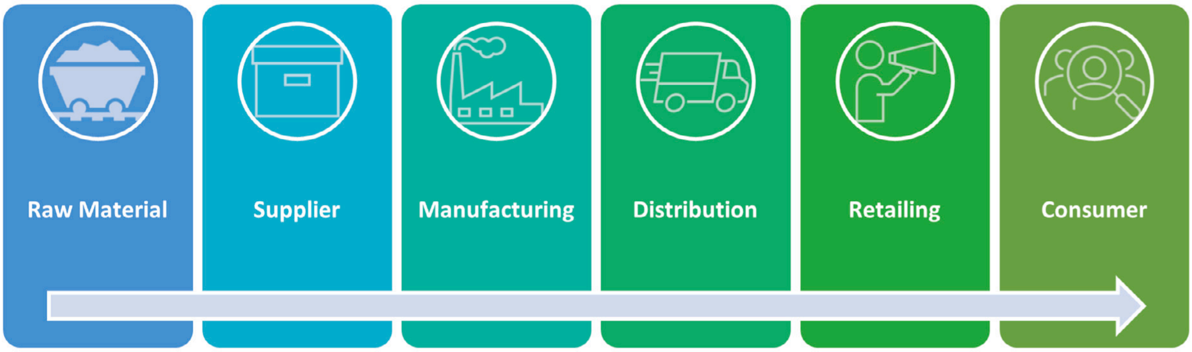

Fig. 2. General SCM process.

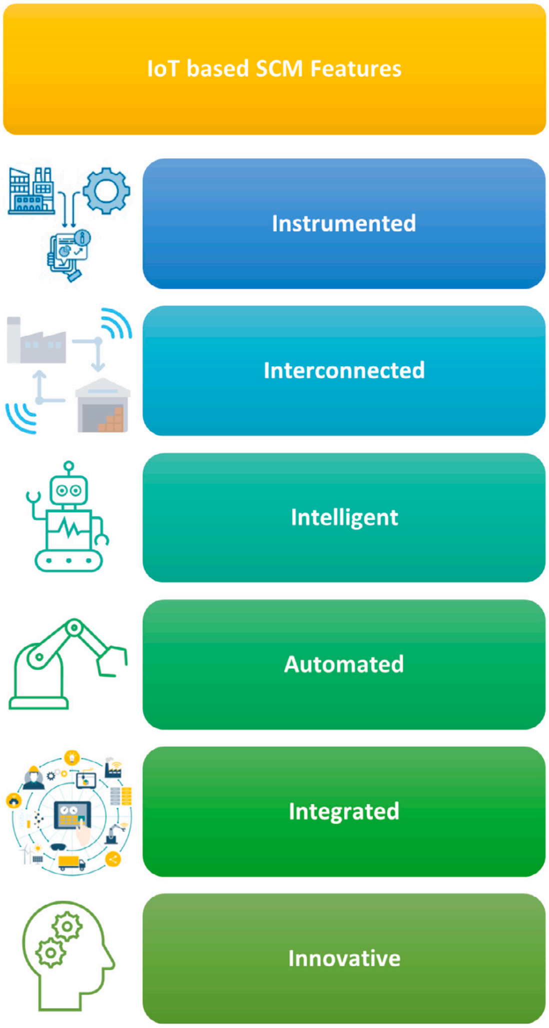

Fig. 3. Features of IoT-based SCM.

Table 1
Comparison of existing literature reviews.

Ref	Year	Study type	Objective	Limitation
[6]	2019	Literature Review	This literature review aims to explore the role of IoT and its impact on supply chain management. The authors discussed IoT technologies and application domains of SCM.	This review does not cover the sensors used to implement IoT-based SCM.
[7]	2020	Bibliometric Analysis	This literature review aims to give a bibliometric analysis of IoT in Supply chain management and logistics. This paper covers the core insights about publications, journals, authors, countries, articles, citations, essential keywords, and some major application domains of research on IoT in supply chain management and logistics.	Only bibliometric analysis is not enough to get a holistic view of research on IoT in supply chain management. This research does not cover the technologies, sensors, and devices used for IoT-based SCM systems.
[8]	2021	Systematic Literature Review	This study aims to analyze the effects of IoT on the performance of supply chain management processes.	Authors only analyzed different SCM processes and the effects of IoT on the performance of SCM processes. This review does not cover the application domains and sensors used to implement IoT in SCM.
[9]	2021	Systematic Literature Review	This study aims to provide an in-depth analysis of literature present on Blockchain-based IoT devices in SCM.	This SLR is limited in scope as this research only discusses Blockchain-based IoT in SCM. The author's insights about the given topic are valuable as analytical depth is present specifically about Blockchain-based IoT in SCM. Still, this SLR lacks a breadth analysis of the IoT-based SCM. Future researchers need SLRs that have in balanced depth and breadth analysis of the topic. As IoT-based SCM is not limited to Blockchain technology, many other emerging technologies like AI, ML, DL, and Big Data Analytics are integrated with IoT-based SCM.

the SCM process is made smart with improved SCM processes. SCM has the following distinguishing features that can be seen in SCM in which IoT is used [5].

1. Instrumented: Information in SCM using IoT is machine-generated, for example, sensors used to collect large amounts of environmental data.
2. Interconnected: The smart objects, business entities, products, and assets all are connected with the help of the Internet and IT systems.
3. Intelligent: Business intelligence and smart analytics optimize decisions for the SCM process.
4. Automated: The whole process of SCM is automated, making it an efficient and better solution with ease of use and fast operations by reducing labor-intensive work.
5. Integrated: SCM using IoT is a set of integrated chained processes. The SCM process is carried out with collaboration between its different stages for joint decision-making and information sharing.
6. Innovative: IoT in SCM creates change and value by introducing new solutions that fit modern-era needs.

Fig. 3 sketches the features of IoT-based SCM. IoT in SCM has revolutionized its process in each stage of SCM, from manufacturing to warehousing and transportation and logistics. At every stage, IoT provides its services in automation, cost-effectiveness, tracking and traceability of products and goods, improved and efficient inventory management, better machine performance, and visible market trends to grow business.

1.4. Relevant literature reviews

The research on IoT-based SCM is increasing continuously. Specifically, when considering the literature reviews, surveys, and SLRs, there appears to be a limited number of such studies. When selecting primary studies for this review, we found only a few literature reviews, and almost all the reviews were particularized to specific areas and were not comprehensive in nature; therefore, it is needed to contribute to the body of knowledge for IoT-based SCM to facilitate future researchers by providing them with a clear and comprehensive overview of the topic. A comparison of existing literature reviews is given in Table 1.

1.5. Research contribution

The gaps or limitations found in previous literature provide the basis for this SLR. Prior literature did not provide an in-depth, comprehensive analysis of literature found for IoT-based SCM. Some previous reviews [6–9] were found to be relevant to the topic.

Still, all these reviews had certain limitations, such as these reviews were not comprehensive in nature or there was a balance missing for depth and breadth of research analysis in given reviews. A Comparison of relevant literature is given in Table 1. This review is the first SLR highlighting the past five years of research on IoT-based SCM. It aims to provide an in-depth overview of the growing field of IoT-based SCM. This study contributes to the body of knowledge by providing a comprehensive review. Along with these findings, this study covers application domains, technologies, sensors, and devices used to implement IoT-based SCM systems. This SLR also highlights the challenges, benefits, and economic and business implications of IoT-based SCM. The finding of this SLR will help practitioners and researchers to get an in-depth review of recent developments in IoT-based SCM.

2. Methodology

This study aims to analyze the literature on IoT-based SCM systematically. An SLR is conducted to find research on IoT-based SCM to accomplish this aim. As recommended by Kitchenham and Charter [10], a process based on three phases is carried out to conduct this study, i.e., (1) Planning Phase discussed in Section 2.1 (2) Conducting Phase discussed in Section 2.2 and (3) Reporting phase discussed in Section 2.3.

2.1. Planning phase

The initial phase of conducting a systemic literature review started with the planning phase. The planning phase constituted formulating research questions, developing a search strategy, identifying quality assessment criteria, and developing a data extraction strategy.

2.1.1. Formulating review questions

This section spotlights motivation review questions that need to be addressed to accomplish the review aim, providing an depth overview of the growing field of IoT-based SCM. Here is the list of review questions, along with motivation.

RQ1: What are available publication channels for IoT and SCM research, especially impact factor journals?

Motivation: To identify IoT research publication channels where genuine and credible IoT and SCM research can be found and to highlight good publication sources for future studies.

RQ2: What is the frequency of publications related to IoT-based SCM over time?

Motivation: To pinpoint research trends related to IoT-based SCM over time.

RQ3: What are the main application domains of IoT-based SCM?

Motivation: To discover the main application domains of SCM where IoT technology is used

RQ4: What technologies or IoT-enabled technologies are utilized for IoT-based SCM?

Motivation: To identify the commonly used IoT technology in SCM.

RQ5: What type of sensors/devices are used for IoT-based SCM?

Motivation: Identify the commonly used sensors/devices IoT technology in SCM. The most crucial components in creating an IoT-based SCM architecture are sensors. Businesses can detect and trace items and environmental conditions using sensors. IoT sensors and their implementation in many SCM application areas require speedy analyses and insightful information for researchers and readers.

2.1.2. Developing search strategy

After formulating the research questions, it is necessary to develop a search strategy. The search strategy consists of selecting online search databases, searching keywords, and designing search queries for an SLR. Search Databases: A search strategy is developed in which digital databases are selected. Scopus and IEEE Xplore are the two online databases searched for this SLR. Search Keywords: Keywords related to the SLR topic are decided in this stage. Proper keywords found for the search query are "Internet of Things", "IoT", "Supply Chain Management", "Supply Chain", and "SCM". Search Query: The given search query was finalized to be applied to selected digital databases, i.e., Scopus and IEEE Xplore. ("IoT" OR "Internet Of Things") AND ("Supply Chain Management" OR "Supply Chain" OR "SCM").

2.1.3. Defining studies selection criteria

When a search query is executed, it is necessary to select relevant literature based on selection criteria that fit the scope of an SLR. PRISMA studies selection protocol is followed for selecting studies for SLR [11]. This protocol needs explicit inclusion and exclusion criteria for selecting studies that match the scope of the systematic literature review. Here, in the planning phase, inclusion and exclusion criteria are defined.

2.1.4. Inclusion and exclusion criteria

The inclusion and exclusion criteria are developed for this SLR to get suitable studies for review findings. Table 2 accurately describes this SLR inclusion and exclusion criteria.

Table 2
Inclusion and exclusion criteria.

Inclusion Criteria	
1	Studies published in the English language will be included.
2	The included study must be published in the Journal.
3	The included study must be published between 2018 to 2022.
4	The included study must have used IoT in SCM.
5	The included study must be relevant to the research scope.
Exclusion Criteria	
1	Studies published in a language other than English will be excluded.
2	Gray literature and conference studies will be excluded.
3	Studies published in a language other than English will be excluded.
4	The study whose full text is unavailable will be excluded.
5	The study published before 2018 will be excluded.

Table 3
Quality assessment criteria.

Item #	QA question	Score	Description
QAC1	Are research objectives clearly stated?	0	No, objectives are not stated.
		0.5	Partially, objectives are stated but not clear.
		1	Yes, objectives are clearly stated.
QAC2	Is research methodology well defined?	0	No, the research methodology is not well defined. It needs to go through references.
		0.5	Partially, the methodology is defined but does not mention specific steps for methodology.
		1	Yes, the methodology is well-defined.
QAC3	Does the study clearly discuss the application domains of Supply Chain Management where IoT is used?	0	No, the study does not clearly discuss the application domains of Supply Chain Management where IoT is used.
		0.5	Partially, the study discusses the application domains of Supply Chain Management where IoT is used but unclearly.
		1	Yes, the study clearly discusses the application domains of Supply Chain Management where IoT is used.
QAC4	Does the study properly discuss the technologies used for IoT-based SCM?	0	No, the study does not correctly discuss the technologies used for IoT-based SCM.
		0.5	Partially, the study discusses the technologies used for IoT-based SCM but unclearly.
		1	Yes, the study adequately discusses the technologies used for IoT-based SCM.
QAC5	Does the study properly discuss the sensors used for IoT-based SCM?	0	No, the study does not correctly discuss the Sensors used for IoT in SCM.
		0.5	Partially, the study discusses the sensors used for IoT in SCM but unclearly.
		1	Yes, the study appropriately discusses the sensors used for IoT-based SCM.

2.1.5. Defining quality assessment criteria

To check the quality of studies to be included in SLR, Quality Assessment Criteria (QAC) have been developed. According to the given QAC, each study is evaluated. Each QAC is associated with a Quality Assessment (QA) question. The answer for each QA question can be yes, partially, or no, and a numeric score is given to these answers, i.e., yes is given a 1 score, partially is given a 0.5 score, and no is given a 0 score. The overall score of each study is calculated by adding the scores for answers to given Q.A. questions. Table 3 gives a brief summary of QAC.

2.1.6. Developing data extraction strategy

After selecting studies that meet QAC, data or information relevant to research questions is extracted. Table 4 lists data items to be extracted from articles and their relevancy to research questions.

Table 4
Data extraction strategy.

Data item no.	Data item	Description	Relevancy
1	Journal, publisher, and impact factor	To find the publication channels for research on IoT-based SCM	RQ1
2	Publication year	To find the publication frequency year wise	RQ2
3	Application Domains	To find the different application domains targeted for research on IoT-based SCM.	RQ3
4	Technologies	To find the latest technologies used for research on IoT-based SCM.	RQ4
5	Sensors	To find the various sensors used for research on IoT-based SCM.	RQ5

2.2. Conducting phase

The SLR was conducted by executing a search query on bibliographic databases to collect relevant studies on IoT-based SCM. After this phase, collected studies were further filtered using the PRISMA methodology. Selected studies were finally passed to quality assessment criteria (QAC). Those that fulfilled QAC were considered final studies from which relevant data according to research questions were extracted and synthesized. This section discusses in detail the steps involved in conducting the phase of the SLR.

2.2.1. Executing search query

In this step, the designed search query, i.e.,("IoT", OR "Internet Of Things") AND ("Supply Chain Management" OR "Supply Chain", OR "SCM"), is executed on Scopus and IEEE Xplore. The search was done on the title, which was limited to the past five years, from 2018 to 2022. Only peer-reviewed journal articles were selected for SLR purposes.

2.2.2. Studies selection process

By executing a search query on Scopus, 146 research studies were retrieved, and by executing a search query on IEEE Xplore, 100 papers were retrieved, in total, 246 papers. All the retrieved studies were saved and managed for further review in the Mendeley Reference Manager. Duplicate studies were removed, and inclusion/ exclusion criteria were applied to retrieved studies to get relevant studies for review. The process of selecting primary studies is depicted using the PRISMA diagram [11] as shown in Fig. 4. A total of 130 primary studies were selected for the further review process.

2.2.3. Quality assessment of studies

Primary studies were selected after screening and eligibility, i.e., studies that met inclusion and exclusion criteria. A total of 130 studies were selected. The Quality Assessment Criteria given in Table 3 were applied to these studies; most of the studies did not meet the QAC as they did not clearly mention the technologies and sensors used in their research, so based on QA questions, those studies that scored less than 4 were excluded for further data extraction. Only studies that meet QAC and achieve a score of 4 or above were included for data extraction and synthesis. A total of 43 studies met the QAC, so these studies were further used for data extraction and synthesis.

2.2.4. Data extraction and synthesis

Data Extraction and synthesis were performed on selected 43 studies that meet the QAC. Data extraction included data items mentioned in Table 4. Data items like journal name, publisher, impact factor, RIS file for all selected studies, publication year, application domains, technologies, and sensors are extracted from selected studies.

2.3. Reporting phase

All the findings from the extracted data are discussed in this section. Each RQ is discussed in detail, and a summary of the extracted data is also given in this section. RQ1 related to the publication channels for IoT and SCM research is discussed in Section 3.1, RQ2 related to publication frequency of literature for IoT-based SCM discussed in Section 3.2, a summary of review findings is given in Section 3.3, RQ3 related to application domains of IoT based SCM is discussed in Section 3.4, RQ4 related to technologies used for IoT based SCM is discussed in Section 3.5, RQ5 related to sensors used for IoT based SCM is discussed in Section 3.6, in addition to these findings a detailed analysis of the challenges, benefits, and economic and business implications of implementing IoT-based SCM have been discussed in Sections 3.7, 3.8, 3.9, and 3.10 respectively. The conclusion of SLR is discussed in Section 4.

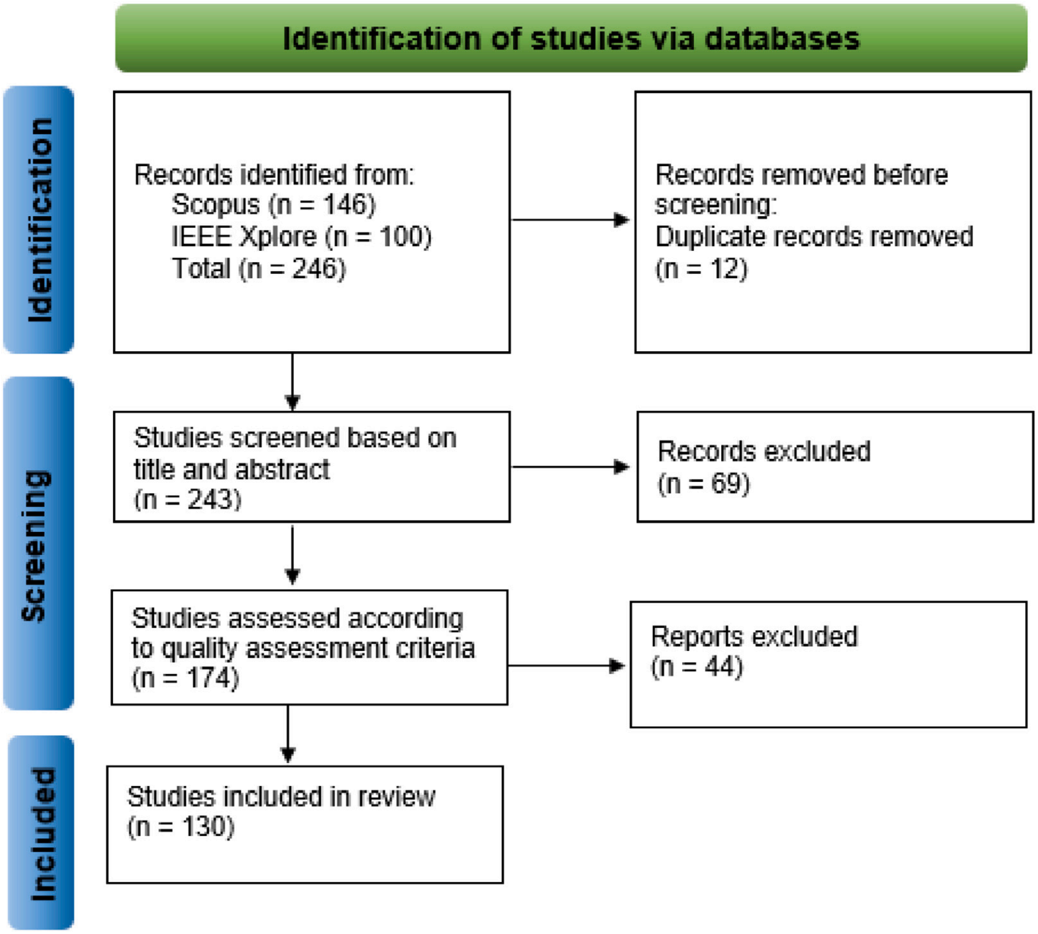

Fig. 4. PRISMA diagram.

3. Results & discussion

3.1. Available publication channels for IoT and SCM research (RQ1)

This section discusses the available publication channels for IoT and SCM. It summarizes publishers, their different journals, and their impact factor found from JCR (Journal Citation Report 2022), along with several studies on IoT and SCM, as shown in Table 5. A total of 43 studies were selected, from which 35 were found to be published in impact factor journals, and 8 were published in journals that are a non-impact factor or have Emerging Science Citation Index (ESCI). Fig. 5 shows the analysis of the top 10 publishers in the literature for IoT-based SCM research.

3.2. Frequency of publications related to IoT-based SCM over time (RQ2)

The frequency of publications of all the retrieved studies is visualized in the given diagram to see whether the research trend is growing. It can be observed that publication frequency increased in 2019 compared to 2018, with a decrease in publication for 2020. It might be due to the pandemic situation due to Covid-19. After 2020, research publication frequency increased, which indicates the growing interest in research for IoT-based SCM. For the year 2022, few publications are observed. There might be a reason that the search for SLR was conducted at the start of 2022, and it is expected that more studies will be published on IoT by the end of this year. Fig. 6 shows the statistics for the frequency of publication over time for IoT-based SCM research.

Fig. 7 shows the correlation between Publishers, Journals, and their impact factor, and the number of studies found for SLR.

3.3. Summary of selected studies

The section gives a detailed summary of selected studies covering the application domains, areas of SCM, technologies, sensors, and devices used to implement IoT-based SCM systems. Table 6 shows the summary of selected studies.

Table 5
Available publication channels.

Publisher	Journal name	Impact factor	Studies
Elsevier	Computer Networks	5.493	1
	Computers & Industrial Engineering	7.18	1
	Future Generation Computer Systems	7.307	1
	Computers in Industry	11.245	1
Emerald Publishing	Industrial Management & Data Systems	4.803	1
	Journal of Enterprise Information Management	5.661	1
Hindawi	Mathematical Problems in Engineering	1.43	1
	Complexity	2.121	1
IEEE	IEEE Access	3.479	17
	IEEE INTERNET OF THINGS JOURNAL	10.238	1
	IEEE Open Journal of the Computer Society	–	1
Inderscience	International Journal of Systems, Control and Communications	–	1
INT ASSOC ONLINE ENGINEERING	International Journal of Online and Biomedical Engineering	–	1
MDPI	Sensors	3.848	1
	Sustainability (Switzerland)	3.889	1
	Social Sciences	–	1
SERSC	International Journal of Advanced Science and Technology	–	1
Springer	Information Technology and Management	2.13	1
	Cluster Computing	2.303	1
	EURASIP Journal on Wireless Communications and Networking	2.559	1
	Information Systems Frontiers	5.216	1
	International Journal of System Assurance Engineering and Management	–	1
	International Journal of Information Technology	–	1
Taylor & Francis	Enterprise Information Systems	4.407	2
The Korean Institute of Information and Communication Engineering	Journal of Information and Communication Convergence Engineering	0.25	1
WILEY-HINDAWI	Wireless Communications and Mobile Computing	–	1
Total Studies			43

3.4. Application domains for research on IoT-based SCM (RQ3)

This section discusses the application domains for research on IoT-based SCM, including Additive Manufacturing Supply Chain, Agriculture and food Supply Chain, Asset Supply Chain, Cold Supply Chain, E-Commerce Supply Chain, Medical and Health Care Supply Chain, Reverse Supply Chain, Electric Vehicle Supply Chain. Fig. 8 shows the main application domains for IoT-based research.

- Additive Manufacturing Supply Chain:
  Additive manufacturing, also known as 3D printing, is a recent advancement in the manufacturing industry. The additive manufacturing supply chain is gaining momentum as it has become more secure and traceable with IoT and Blockchain. Authors in [30] contributed to the IoT-based additive manufacturing supply chain.
- Agriculture & Food Supply Chain:
  The agriculture and food supply chain is the process of supplying raw crops and food products to manufacturers and retailers. The agriculture and food supply chain process continues “from the farm to the table”. All the activities related to food and crops are managed carefully using the agriculture and food supply chain. With technological advancement, IoT-based agriculture and food supply chains are introduced, which makes the whole process of agriculture and food supply chain automated, traceable, secure, and reliable. IoT-based SCM also solved issues like perishability and food waste. The majority of studies found in the literature are on agriculture, and food supply chains, such as authors in [14,18,21,22,24,27,35,36,39,41–43,52] contributed towards IoT-based agriculture and food supply chain. Authors also used IoT-enabling technologies like Blockchain, RFID, Cloud, and AI in agriculture and the food supply chain.

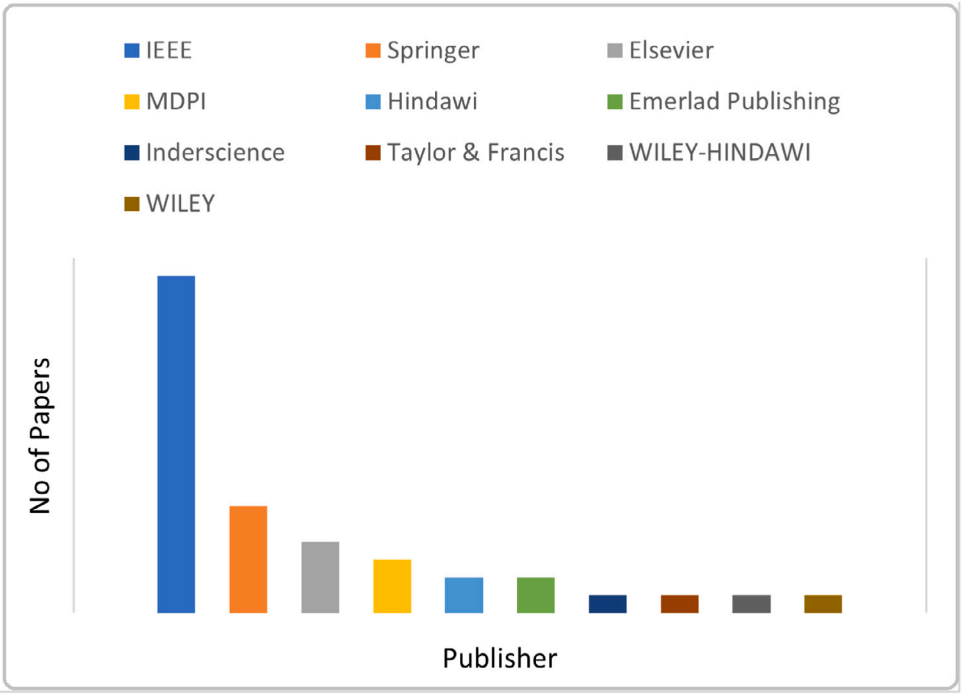

Fig. 5. Top 10 publishers for IoT-based SCM research.

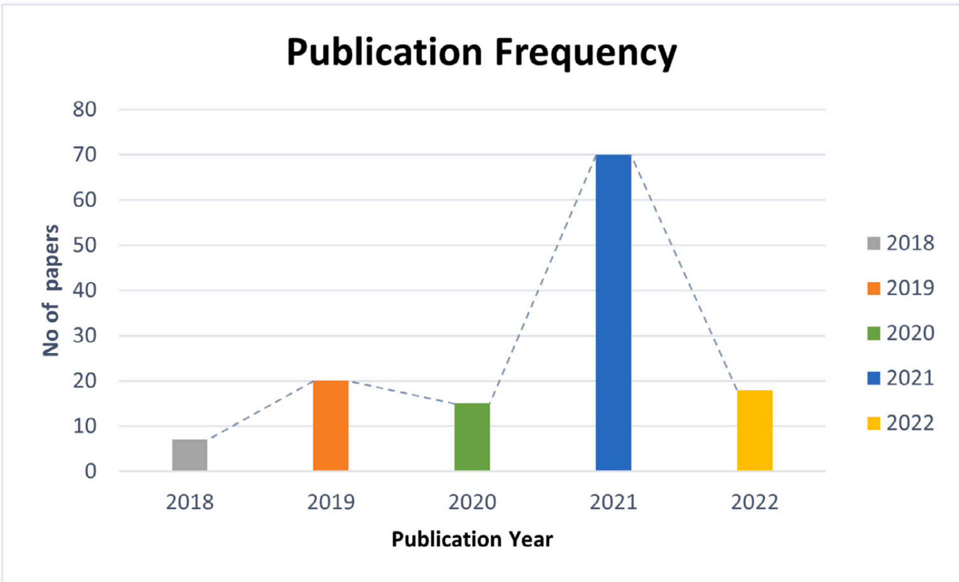

Fig. 6. Year-wise publication frequency.

- Asset Supply Chain:
  Assets are significant and are of great value to organizations. Asset SCM is used to monitor and control organizations' assets. The asset supply chain process consists of activities like registration of assets, control and maintenance of assets, and monitoring and distribution of assets. Authors in [20] contributed to IoT-based asset SCM. The authors created an IoT-based asset SCM to monitor and control the assets using NFC technology.
- Cold Supply Chain:

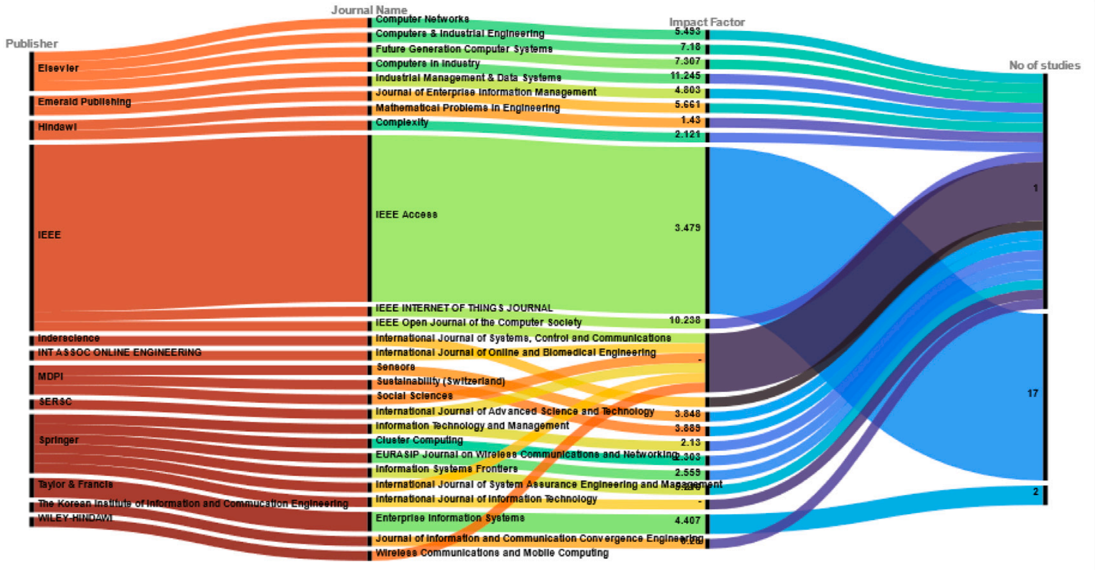

Fig. 7. Publishers and their journals with impact factor and no of studies.

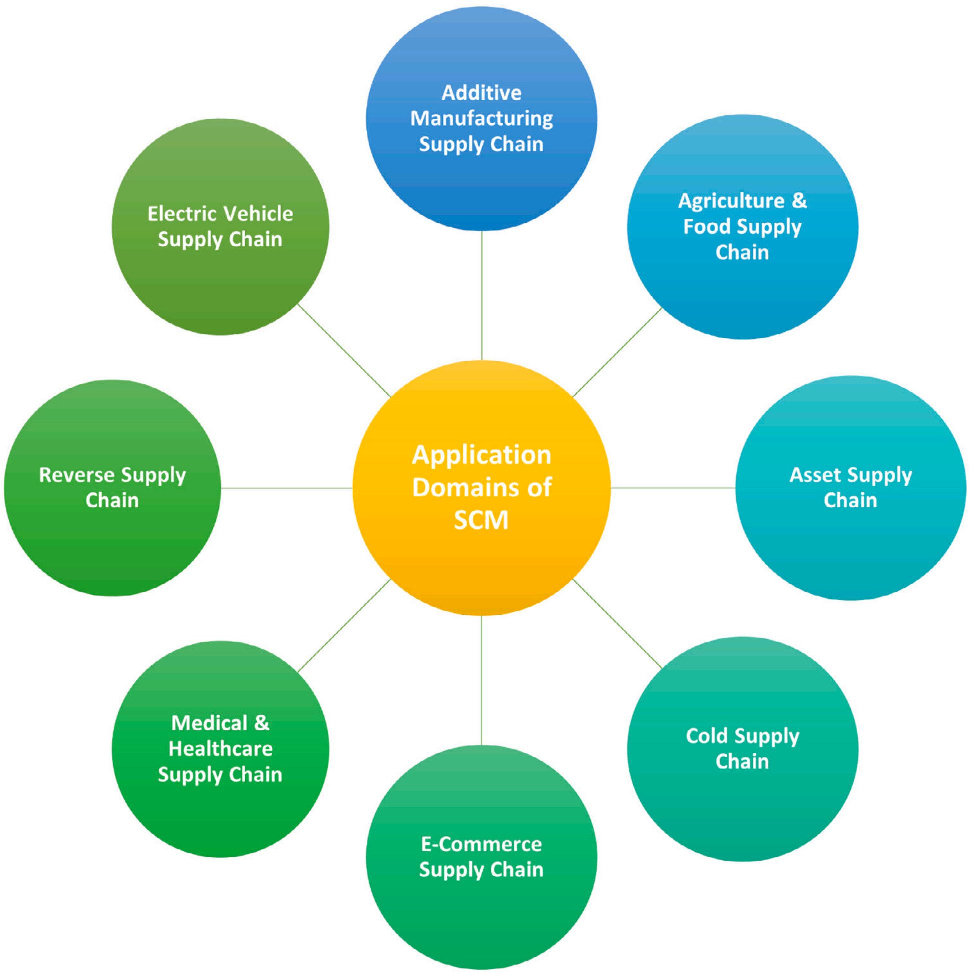

Fig. 8. Application domains for IoT-based SCM research.

Table 6
Summary of selected studies.

Ref	Applications domain	Area	Technologies	Sensors & devices
[5]	Supply Chain Management	Tracking	RFID	GPS, Humidity, Temperature & Tire Pressure Sensor
[12]	Supply Chain Management	Tracking & Monitoring	RFID	GPS
[13]	Cold Supply Chain	Quality & Occupational Safety Risks	IoT, Cloud & AI.	Microsoft Band 2
[14]	Agriculture & Food Supply Chain	Information sharing	Cloud	Temperature & Humidity Sensor
[15]	Medical & Healthcare supply chain	Traceability	RFID	NA.
[16]	Supply Chain Management	Traceability	Blockchain, Smart Tags	NA.
[17]	Supply Chain Management	Traceability	Blockchain	NA.
[18]	Agriculture & Food Supply Chain	Logistics	RFID	NA.
[19]	Reverse Chain Management	Inventory Monitoring	RFID	Temperature & Humidity Sensor
[20]	Asset Supply Chain	Control & Monitoring	NFC	GPS
[21]	Agriculture & Food Supply Chain	Logistics	RFID	GPS
[22]	Agriculture & Food Supply Chain	Traceability	Blockchain	NA.
[23]	Supply Chain Management	Tracking	Blockchain	GPS, Gyro Sensor & Motion sensor
[24]	Agriculture & Food Supply Chain	Tracking & Quality Monitoring	RFID,Blockchain	Thermistor based Temperature Sensor
[25]	Supply Chain Management	Warehouse Management	RFID	Temperature, Humidity, Weight Sensor
[26]	Supply Chain Management	Ordering and Inventory Management	Artificial Intelligence (AI.)	Accelerometer & Hall Sensor
[27]	Agriculture & Food Supply Chain	Traceability	Blockchain, Cloud	NA.
[28]	Supply Chain Management	Risk Management	RFID	GPS, Camera
[29]	Supply Chain Management	Traceability	Blockchain	NA.
[30]	Additive Manufacturing Supply Chain	Traceability	Blockchain	Camera
[31]	Supply Chain Management	Risk Management	RFID	Cameras or Video Sensor, Temperature Sensor, Humidity Sensor, Smoke Sensor & GPS
[32]	School Uniform Supply Chain	Information Sharing	RFID	GPS
[33]	Supply Chain Management	Traceability	Cloud	GPS, Accelerometer, Thermal Sensor, Occupancy Sensor, Light Sensor & Door Sensor
[34]	Medical & Healthcare Supply Chain	Security Analysis	RFID	NA.
[35]	Agriculture & Food Supply Chain	Quality Monitoring & Control	Cloud	Temperature, Humidity, Color, Light & Gas Sensors
[36]	Agriculture & Food Supply Chain	Performance Measurement	RFID	NA.
[37]	Medical & Healthcare Supply Chain	Manufacturing	Blockchain	Temperature Sensor, Pressure Sensor & Cameras
[38]	Supply Chain Management	Smart Shipping	Blockchain, Cloud	Temperature Sensor, Humidity Level Sensor, Light Exposure Sensor & GPS

(continued on next page)

Table 6 (*continued*).

[39]	Agriculture & Food Supply Chain	Communication Model	–	Ultrasonic, Light, Electric Conductivity Sensor, Carbon Dioxide Sensor, Air temperature and Humidity Sensor, Ph Sensor, Liquid Level Sensor & Wire Temperature Sensor.
[40]	Supply chain management	Traceability	Blockchain, RFID	NA.
[41]	Agriculture & Food Supply Chain	Traceability	Blockchain	Soil Moisture, Soil Temperature & Air Temperature Sensor
[42]	Agriculture & Food Supply Chain	Traceability	Blockchain, AI, RFID	GPS
[43]	Agriculture & Food Supply Chain	Traceability	NFC, RFID	Temperature & Humidity Sensor
[44]	Electric Vehicle Supply Chain	Tracking	Blockchain, Cloud, QR code	Tire Pressure Sensor, Accelerometer & Battery Sensor
[45]	Medical & Healthcare Supply Chain	Tracking	Blockchain, Cloud, QR code	Temperature Sensor
[46]	Supply Chain Management	Information Sharing and Traceability	RFID, Blockchain	NA.
[47]	E-Commerce Supply Chain	Information Sharing	RFID	NA.
[48]	Supply chain Management	Warehouse Management	RFID, Cloud, Agent-Based System	NA.
[49]	Supply Chain Management	Inventory management	Cloud	NA.
[50]	Supply Chain Management	Decision Making	Blockchain, RFID	GPS, Humidity, Light, Pressure, & Temperature
[51]	Supply Chain Management	Traceability	RFID	GPS, Humidity, Temperature, & Light
[52]	Agriculture & Food Supply Chain	Traceability	Blockchain, QR code	NA.
[53]	Supply Chain Management	Logistics	AI	Pyrometer, Accelerometer & GPS

The cold supply chain is temperature-controlled. Generally, it is used for food, vaccines, and medicine that must be kept in a temperature-controlled environment. The cold supply chain produces, stores, and delivers these foods, vaccines, and medicines that need a constant low-temperature range. Authors in [13] worked on real-time frozen and fresh food monitoring using IoT-based cold chain management. The author also considered occupational safety risks in the cold supply chain.

- E-Commerce Supply Chain:
  An E-Commerce supply chain is the strategic management process for all the activities on which e-commerce is based, such as the production of raw materials, manufacturing of products, logistics, inventory management, and last-mile delivery of the product to the end customer. Authors in [47] contributed towards IoT-based E-Commerce supply chain to improve the production process and overall e-commerce supply chain efficiency.
- Medical & Healthcare supply chain:
  The healthcare supply chain is the management of medical and Healthcare activities like manufacturing and distributing medical and Healthcare supplies, including medicines, to the patients. Authors in [15,34,37,45] contributed towards IoT-based healthcare supply chain to improve the overall healthcare supply chain process by making it more secure using RFID and Blockchain technology.
- Reverse Supply Chain:
  The reverse supply chain is the reverse of the traditional supply chain process. Here, the evolution of the product is made from the customer to the manufacturer. In recent years, the number of returned products to retailers has increased. The reverse supply chain manages the products customers return by reusing or disposing of the product. Authors in [19] contributed to the IoT-based reverse supply chain to identify that reusable returned products can be further repaired or recycled.
- Electric Vehicle Supply Chain:
  An Electric Vehicle Supply chain is a futuristic supply chain of electric vehicles to manage and track electric vehicles. Authors in [44] contributed to the IoT and Blockchain-based electric vehicle supply chain. The authors developed a secure, transparent, and efficient way to track the whole life cycle of the electric vehicle supply chain.

3.5. Main technologies used for IoT-based SCM (RQ4)

This section discusses the main technologies that are used for IoT-based SCM. Fig. 9 shows the main technologies that are used mostly for IoT-based SCM.

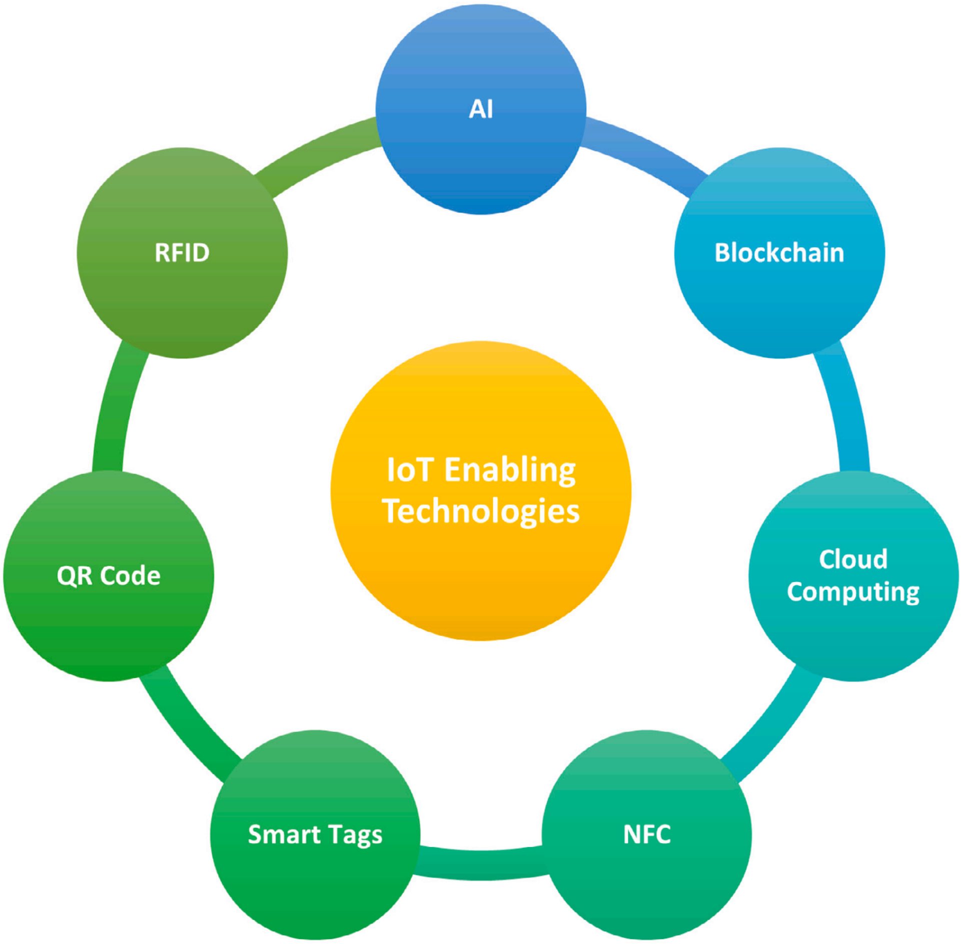

Fig. 9. Main technologies used for IoT-based SCM research.

- Artificial Intelligence (AI)

  AI is the most powerful IoT-enabling technology that can be used to automate the process of SCM. AI can help major stockholders of SCM, like managers, suppliers, and retailers, in predictive analytics and defect detection about their products and goods.

  Authors in [26] utilized AI's power to analyze defective product patterns. The authors developed an intelligent algorithm highlighting defective products and serving them for safety stock ordering. Defective products are inspected using an AI algorithm and are returned to the vendor.

  Backorders are a type of order for a product that cannot be completed or fulfilled currently due to the unavailability of that product due to lack of supply. To solve this problem, authors used Machine Learning techniques under AI to predict the backorders for particular products. Authors contributed to serving in the optimization of the SCM process. All stockholders, suppliers, managers, and retailers highly demand the prediction of backorders. Solving the problem of backorders using AI will ultimately build customer trust and help grow business.

  Authors in [53] identified optimal routes using AI to improve vehicular logistics. The authors used AI techniques to find alternate optimal shipping routes to avoid delayed shipment of urgent items.

  Fuzzy logic is a rule-based AI technique implemented for decision-making. Authors in [13] used fuzzy logic to measure workers' occupational safety risk in a cold chain facility according to their health status.

  Authors [48] developed an agent-based system with the help of RFID and cloud computing. This agent-based system provides intelligent shelf service that can recommend desired products to the customers and provide real-time product information to facilitate dynamic response to the customer's demand and market changes, especially for hot-sale products.

- Blockchain

  Traditional IoT-based SCM suffers from issues of transactions that are not verifiable. Traceability is difficult for products. Therefore, Blockchain is the best solution for these problems. Blockchain can make IoT-based SCM secure, transparent, and verifiable.

Authors in [17] also created a Blockchain-based framework for the traceability of electronic supply chains, especially tracking and tracing microelectronics chips and commercial off-the-shelf (COTS) parts used in electronic devices. They used Hyperledger for the implementation of the proposed framework. This framework will help all manufacturers, distributors, and customers track the origin of electronic parts and trace their origin so that they can be protected from counterfeited electronic devices.

Traditional food traceability systems are centralized and can have data tampering and sensitive information disclosure. To provide a secure and reliable solution for the food supply chain, authors in [22] developed a traceability system for the food supply chain based on Blockchain technology. They implemented this system using Ethereum Blockchain technology. This system for food traceability is decentralized in nature and protects sensitive business information using smart contracts. This system provides a secure environment for the food supply chain by ensuring information protection, avoiding spam attacks, and robustness of the system in which there is no risk of data tampering. Perishable food items are susceptible to environmental conditions, so tracking and tracing them at each stage of the supply chain is necessary.

Authors in [24] used Blockchain technology to create a tamper-proof database for food packages to track and monitor the quality of food packages scanned at retailers, logistics, and storage areas. All the real-time sensor data for each scanned food package is updated in Blockchain and provides a digital tamper-proof history of food packages. Authors in [52] proposed a system for improved food safety in the food supply chain using IoT and Blockchain technology. The proposed system uses a QR code in which all information related to food items is stored, including the date of manufacturing and expiration. Blockchain technology prevents introduction and entry of fake or illegal food items so customers can get genuine food products. Spoilage of perishable food items is a common issue.

The current SCM system does not provide any mechanism to monitor the quality of perishable food items. Authors in [27,42] worked on the traceability perishable food supply chain by introducing a feasible solution based on IoT and Blockchain. Every shipment of perishable food items is equipped with IoT sensors, and quality is recorded using distributed ledger and smart contracts technology and shared among all the stakeholders.

Current agri-food supply chains based on IoT technology are centralized and have a single point of failure. The traceability of crops and food is complex, and farmers and buyers have no communication channel. These IoT-based agri-food supply chains are not energy efficient. To deal with all these issues, authors in [41] proposed a complete solution for agri-food supply chains based on Blockchain and IoT. Farmers can acquire information about the crop, soil temperature, and soil quality to improve crop production using IoT. The growth of crops can be tracked and recorded. Blockchain can help manage real-time updates about food items' safety status to all stakeholders in a decentralized way. The authors also proposed an efficient low-energy consumption clustering IoT protocol for the agri-food supply chain to increase network life and reduce energy consumption.

Authors in [43] also proposed a Blockchain and IoT-based traceability system for the agri-food supply chains so that consumers can have a transparent view of the whole food journey from farm to table. And supervisory team can have online inspections of food quality and working practices.

Authors in [28] developed a Blockchain and IoT-based system based on distributed ledger and smart contracts for the traceability of products. In this system, the whole process, i.e., product registration, transferring, and tracking, is carried out using smart contracts. One of the issues in traditional product traceability systems is the "Man-in-the-Middle" attack. The authors also introduced an event response mechanism in which the signature generated for the transaction event is verified to ensure the identity of both parties for the transaction to avoid the "Man-in-the-Middle" attack.

Authors in [23] used Blockchain to monitor the service quality of IoT-based applications used for industries. The authors considered the use case of transportation of furniture. Service quality is measured by comparing the expected performance of the application with the actual performance.

Authors in [30] proposed a Blockchain and IoT-based solution for the proof of authenticity of 3D printing of products to enable trust among the stakeholders involved in the additive manufacturing process. The authors used an Ethereum-based smart contract to trace the customer-initiated transactions for the manufacturing process.

Authors in [37] used Blockchain and IoT to manufacture medical devices and supplies. The authors considered the COVID-19 pandemic, during which it was challenging to use a traditional SCM system for medical devices and supplies as traditional SCM lacks secured traceability. The authors developed a Blockchain, IoT-based solution implemented using Ethereum smart contracts to manufacture medical devices and supplies digitally. This makes the whole process of digital manufacturing transparent, reliable, secure, auditable, and traceable. Authors in [45] developed a mobile application for pharmacy. Authors digitized the process of buying medicines by introducing IoT and Blockchain-based solutions in which consumers can verify the authenticity of the medicine they purchase by scanning the QR code associated with each medicine to eliminate counterfeited medicine purchases. Using IoT and Blockchain, real-time temperature conditions of medicine can also be monitored. This mobile application is implemented using the NEM Blockchain. The authors also facilitated the purchasing of medicine using cryptocurrency.

Authors in [38] also contributed to the medical supply chain by introducing Blockchain and IoT-based "cryptocargo" for the smart shipping of Vaccines. The implementation of "cryptocargo" is also based on the Ethereum Blockchain. Using this proposed innovative shipping solution, the conditions like temperature, humidity, luminosity, and lid status of vaccines inside cargo can be monitored in real-time, allowing violations to be tracked and recorded with the help of Blockchain using smart contacts.

SCM requires mutual trust among the stakeholders so that every stakeholder, i.e., supplier, manufacturer, and retailer, is in the loop. The insurance of trust among all the stakeholders is a difficult task. Authors in [40] developed a trust model for SCM using IoT and Blockchain, so all the data generated by IoT devices and events that occurred during the supply chain process

are recorded using Blockchain technology. This establishes trust among all the stockholders as tracking, tracing, and managing products becomes easy and do not require any trusted intermediary.
Pre-owned vehicles are purchased from a third party, and the buyer does not know the authentic information about the vehicle, like its battery life, performance, and charging records. To solve this issue for the pre-owned electric vehicle supply chain, authors in [44] introduced IoT and Blockchain solutions. The authors used Ethereum Blockchain for implementation purposes. Buyers and sellers using this system can communicate all the details about the electric vehicle, like manufacturing, shipping info, owner details, battery information, maintenance reports, police reports, accident records, etc., directly and are shared with the buyer transparently. The authors also introduced cryptocurrency payments for the betterment and ease of the electric vehicle ecosystem.
Authors in [46] performed simulations for both traditional scenarios of order management and simulations of Blockchain and IoT-based scenarios for order management to observe the performance of both. Authors observed that Blockchain and IoT-based scenarios provided better performance for order management by introducing transparency in transactions, effortless information sharing using RFID, collaboration among stakeholders, and traceability of products using Blockchain technology.
Agile supply chains are based on the "sense and respond" mechanism. Authors in [50] introduced a framework for Modern Agile supply chains with IoT technology to sense and respond quickly to the changes during the supply chain process and Blockchain technology to ensure trust and security in agile supply chains.

- Cloud Computing
  IoT-based SCM can be made more reliable by using cloud solutions for managing data related to inventory or processing of sensor data via cloud computing.
  Authors in [13] used a centralized cloud database to store dynamic data collected from sensors In the cloud supply chain and static data collected from real-life operations of the cold supply chain.
  Authors in [14] proposed a reference architecture for IoT-based logistics information systems in agri-food supply chains. The authors introduced a smart logistics cloud system that provides storage and processing for various scenarios like event management, product labeling, and registration; product recalls if a food incident occurs; and quality forecasting based on data collected via sensors.
  Authors in [27] also used cloud computing for food traceability. Cloud provided real-time performance monitoring, database management, durable replication of data, and account privileges.
  Authors in [33] used the FIWARE cloud platform for their system development to improve the overall logistics process, including data sharing and processing.
  Authors in [35] proposed a mobile application-based system to monitor the condition of perishable food. Authors used the cloud for data storage to store the sensor's data that are installed in close food storage areas. Users can monitor the real-time condition of perishable food using the mobile app.
  Authors in [38] used cloud storage for their smart shipping system of vaccines named "cryptocargo" based on IoT, Blockchain, and cloud. The cloud server stores monitoring data of vaccines. The authors also created a mobile application, "DAapp", that provides 24/7 access to the monitoring data stored on the cloud and Blockchain. Authors in [44] used Blockchain cloud storage for the pre-owned electric vehicle supply chain to monitor the performance of the electric vehicle. Authors in [45] used cloud storage for their mobile app for the medical supply chain. Authors in [49] used cloud computing to develop collaborative management and information-sharing platforms for supply chain inventory management.
- NFC
  NFC stands for "Near field communication". NFC technology is used for wireless data sharing among devices that are in proximity. Modern SCM uses NFC for various tasks, including monitoring of assets and traceability of products. Authors in [20] used NFC tags for asset monitoring purposes in the asset supply chain. The authors developed a mobile application to monitor and control the asset. Authors in [43] used the NFC tag for the traceability of food products. NFC tags were deployed on food packages to be tracked.
- Smart Tags
  Authors in [16] contributed to developing verifiable SCM by introducing a Blockchain solution. The authors used Ethereum Blockchain technology and distributed ledger technology, the backbone of Blockchain, to create a Smart Tag "DL-Tag" to manage decentralized, privacy-preserving, and verifiable labeling of products. The customer and all the stockholders can verify the product's authenticity. This innovative Tag solution will prevent customers from buying counterfeit products sold as original products.
- QR Code
  The QR code or "Quick Response Code" is a two-dimensional barcode that stores the information. QR codes are square-shaped and contain a series of dots that store information. Modern SCM uses advanced QR codes that are more robust. Authors in [44] used the Ethereum-generated QR code used in the verification process for pre-owned electric vehicles. Ethereum-generated QR code can never be tampered with as it is associated with an Ethereum Blockchain address. This uniqueness creates trust among all the stockholders. The authors introduced this Ethereum-generated QR code for the pre-owned electric vehicle supply chain. Whenever a person wants to buy a pre-owned electric vehicle, he will get all the information, history, details, and performance of the vehicle using an Ethereum-generated QR code.
  Authors in [44] also used a NEM Blockchain-based QR code for the medical supply chain to get the medical information, including its manufacturer details, price, tracking details, manufacturing date, and expiry date. Any customer or stakeholder can verify the medicine using a mobile application by scanning the QR code.

- RFID
  Authors in [5,12] used RFID to track the products; an RFID tag is attached to each product and scanned using an RFID reader. After scanning the products, all information related to the product, like its production, expiry date, and warranty period, is stored on the website, where suppliers and managers can get all the information about the products. The use of RFID introduces transparency in the supply chain process.
  Authors in [18,43] designed an IoT-based food safety supervision and traceability system in which RFID is used at each stage of the supply chain. The information about food is collected from raw material enterprises, manufacturers, logistics distributors, and sellers using RFID tags. It helped in food safety and traceability to monitor the entire food supply chain process "from the farm to the table". If any food incident occurs, the supervisory department can monitor it easily as data of all stages about food items are added to the food information database. Authors in [21,36,39,42] used RFID for the inspection and identification of agricultural products.
  Authors in [19] used RFID technology in the reverse supply chain to identify the returned products. RFID is also used for warehouse management tasks like warehousing of products, transfer, inventory management, picking and distribution of products [25,31,46,47]. The authors used RFID technology to monitor the pledges for financial risk management in supply chains.
  Authors in [24] integrated Blockchain with RFID to create a transparent and secure food supply chain. Authors used RFID at the physical layer and Blockchain at the cyber layer. When food packages are scanned using RFID at the food packing area, logistics, storage, and retailer within the supply chain, the real-time data using RFID related to food packages are updated in Blockchain, providing a tamper-proof digital history of food packages.
  Authors in [32] used RFID in the school uniform supply chain. The authors emphasized integrating the use of RFID in each link of the supply chain. RFID is used in production, storage, distribution, and sales links so that all the stockholders, including customers and managers, get the correct product information.
  Authors in [15] used RFID technology in the healthcare supply chain. Authors in [34] used RFID technology in the medical supply chain to authenticate medicine and drugs; authors considered the case of COVID-19 kits and implemented RFID on COVID-19 kits to protect patients from counterfeited drugs. This also served in brand protection and logistics management.
  Authors in [40] proposed a trust model with respect to information sharing in SCM. Authors suggested using RFID for storing information about products as this technology is quick response technology and suitable to establish trust between stockholders when sharing information regarding products.
  Authors in [48] used RFID to develop an intelligent product shelf that uses RFID tag information about products to provide customers with the actual time status of inventory and out-of-stock status for products on hot sale. This service also helped warehouse management to make instant replenishment for hot sale products to meet customer needs.

3.6. The sensor used for IoT-based SCM (RQ5)

Sensors are the main components of IoT-based systems. In IoT-based SCM, sensors play a vital role in collecting various kinds of data. Sensors help track and monitor products. Fig. 10 shows the list of sensors in the literature for IoT-based SCM. This section discusses sensors used in review studies and analyzes in what application domains of SCM these sensors were utilized. Fig. 11 clearly shows sensors and application domains of SCM where those sensors were used.

- Accelerometer
  An accelerometer is a sensor that measures acceleration or vibrations and is widely used in shipments or containers. Accelerometer monitors the mechanical shocks, bangs, and trans-shipments a container suffers [33]. Authors in [44,53] used an accelerometer to measure the acceleration or speed of a vehicle.
- Battery Sensor
  Battery heat and charging time sensors are used in electric vehicles to monitor their performance [44].
- Camera Sensor
  The camera sensor is used to identify products [28]. Authors used camera sensors in additive manufacturing to record the 3D printing process [30]. Authors in [31] used the camera to monitor warehousing activities. Authors in [37] used the camera to monitor the manufacturing process of medical and Healthcare supplies.
- Color Sensor
  The color sensor, also known as the photoelectric sensor, is used to detect the color of objects. Authors in [35] used color sensors to monitor perishable food, and authors used this sensor to monitor vegetable freshness.
- Gas Sensor
  A gas sensor detects the presence of gases in the air. Authors in [35] used gas sensors to maintain perishable food quality in a cold storage area. A gas sensor detects the presence of gases in the air. Authors in [35] used gas sensors to maintain perishable food quality in a cold storage area. The gas sensor is also used to measure the amount of Carbon dioxide gas in the air, and it is used to measure the quality of air. It is also used in the crop health monitoring system to check the quality of air required for crop growth [39].
- GPS
  Authors in [5,12,33,38,42,50,51,53] used GPS for outdoor tracking of logistics vehicles to ensure the safety of products onboard. Authors in [20] used GPS sensors in the asset supply chain to track and monitor the assets. Authors in [21] used GPS sensors in the transportation system of agricultural products. Authors in [23] used GPS sensors to track vehicles in transport and delivery systems. GPS sensor is used to track and monitor financial pledges [28].

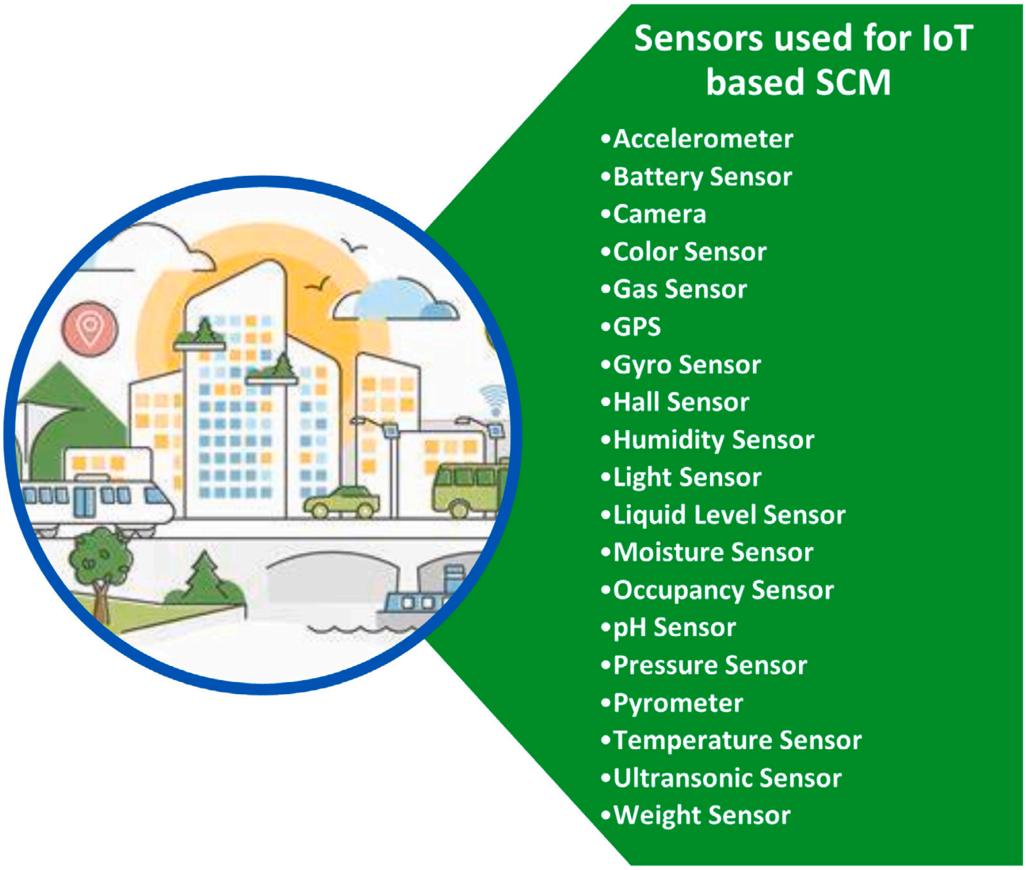

Fig. 10. Sensors used for IoT-based SCM.

- Gyro Sensor
  A Gyro sensor is used to sense the direction. Authors in [23] used the Gyro and GPS sensors in transport and delivery systems to track the vehicle.
- Hall Sensor
  Hall sensors detect the presence and magnitude of the magnetic field with the help of the hall effect. Authors in [26] used hall sensors in inventory management to detect the attachment/ detachment of inventory tags.
- Humidity Sensor
  A humidity sensor is used to measure the number of water vapors. Authors in [5] used humidity sensors in intelligent transportation systems for distributing products. Authors in [14] used humidity sensors to monitor the transport conditions in the agri-food supply chain. Authors in [19] used humidity sensors in the smart container used for the reverse supply chain. Authors in [25,31] used humidity sensors in warehousing to detect the humidity of inventory. Authors in [35] used humidity sensors in the close storage area of perishable food to measure the humidity of food. Authors in [38] used humidity sensors to measure the humidity of medical supplies. Authors in [39] used humidity sensors to measure the temperature of the agricultural environment. Authors in [43] used humidity sensors in agriculture and food supply chains to measure the humidity of food storage areas. The authors used humidity sensors to measure the environmental parameters for logistics.
- Light Sensor
  The light sensor is used to detect the intensity of light. Authors in [33] used light sensors in a container to monitor shipment theft and manipulation hazards. Authors in [35] used light sensors in the closed storage area to detect the light changes to monitor the perishable food freshness. Authors in [38] used a light exposure sensor to detect the opening status of the container. Authors in [39] used light sensors in crop growth monitoring. Authors in [50] used light sensors for agile supply. Authors in [51] used light sensors in tracing the products.
- Liquid Level Sensor
  The liquid level sensor measures the liquid level by measuring the liquid height. Authors in [39] used liquid-level sensors in crop growth monitoring to measure the level of water given to the crop according to its growth.
- Moisture Sensor

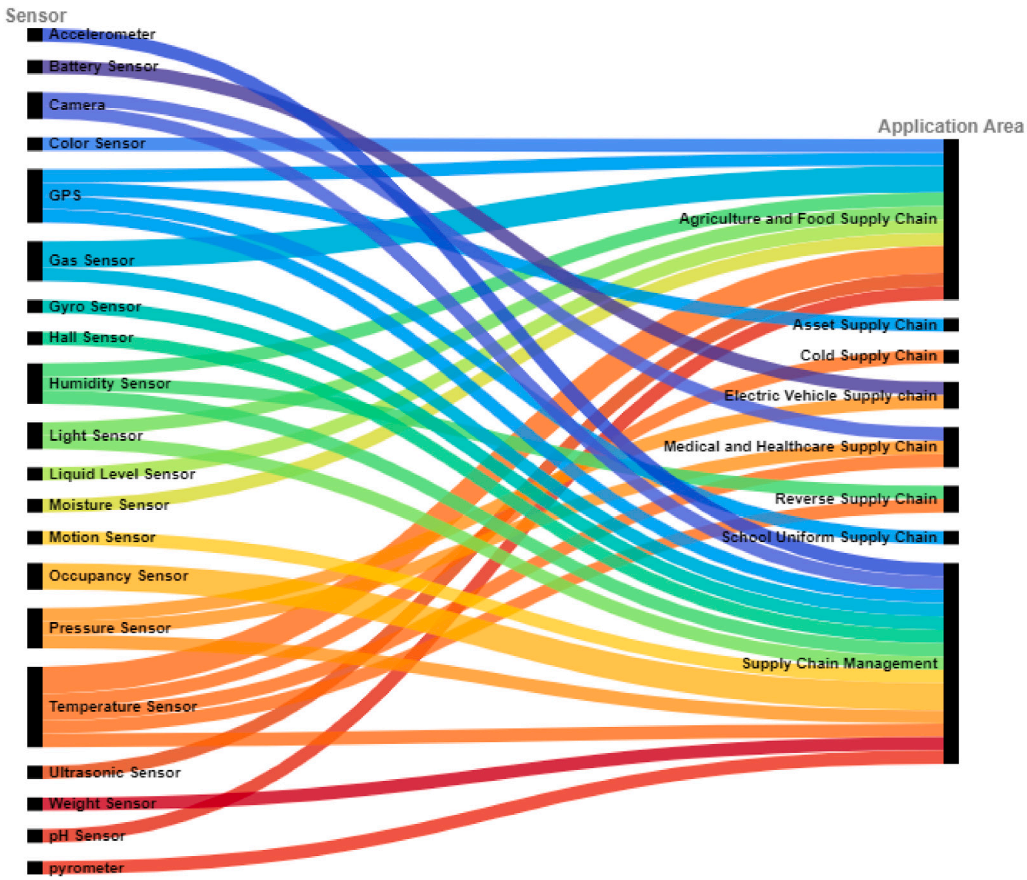

Fig. 11. Sensors used for different application domains in IoT-based SCM.

A moisture sensor detects the moisture or amount of water within a material sample. Authors in [41] used moisture sensors to monitor crop growth in agriculture and the food supply chain by detecting the volume of water in the soil.

- Motion Sensor
  The motion sensor is used to monitor moving objects. Authors in [23] used motion sensors in transport and delivery systems to track the disorientation of transportation vehicles from specific routes.
- Occupancy Sensor
  The occupancy sensor is used to the presence of people or living objects like animals in the area. Authors in [33] used occupancy and door sensors in a shipment container to monitor the theft and manipulation hazards in shipment. The occupancy sensor helped to monitor the presence of the unauthorized person, and the door sensor helped to trigger an alarm when the door of the shipment opened without authorization for theft and manipulation.
- pH Sensor
  pH sensor measures the acidity or alkalinity of liquid or water. Authors in [39] used pH sensors to measure the pH level of water used by crops in agriculture and the food supply chain.
- Pressure Sensor
  The pressure sensor is used to measure the pressure of gases and liquids. Authors in [37] used pressure sensors to manufacture medical supplies. The pressure sensor is also used to monitor the tire pressure in the vehicle for smart transportation [5]. Authors in [44] also used pressure sensors to measure an electric vehicle's tire pressure.
- Pyrometer
  The pyrometer measures the high-temperature level by measuring the object's heat radiation. Authors in [53] used a pyrometer for the logistic vehicle's engine and wheel axle temperatures.
- Temperature Sensor
  A temperature sensor measures the degree of hotness or coldness in an object. Authors in [5,50] used temperature sensors in smart transportation systems for distributing products. Authors in [14] used temperature sensors for their smart agri-food logistics environment. Authors in [19] used the temperature sensor in the smart container for the reverse supply chain. Authors in [24] used temperature sensors in cold food supply chains as it is necessary to maintain the temperature in cold food supply

chains. Authors in [25,31,51] used temperature sensors in warehousing to monitor the environment temperature. Authors in [35] used temperature sensors in closed storage areas of perishable food to maintain the freshness of perishable food. Authors in [37,38,45] used temperature sensors to maintain the temperature of medical supplies and temperature-sensitive shipments like vaccines. Authors in [39] used temperature sensors to measure the temperature of the agricultural environment. Authors in [43] used temperature sensors in agriculture and food supply chains to measure the temperature of food storage areas. Temperature sensors are not limited to the above application domains of SCM. It is also used to measure the temperature of the soil for crop growth monitoring. Authors in [41] used temperature sensors to monitor crop growth in agriculture and the food supply chain. The temperate sensor is also used to measure the temperature of nutrient solutions in hydroponic farms for smart farming and irrigation systems [39]. Temperature sensors are also used to monitor a specific temperature level. Authors in [33] used a thermal temperature sensor to monitor the internal atmospheric conditions of the shipment container.

- Ultrasonic Sensor
  The ultrasonic sensor is used to measure the distance of the target object with the help of ultrasonic sound waves. Authors in [39] used ultrasonic sensors to measure the water level.
- Weight Sensor
  A weight sensor is used to measure the weight of objects as it is connected to a weight scale. Authors in [25] used weight sensors in warehousing.

This SLR also presents in this section a comprehensive understanding of the challenges, benefits, and economic and business implications of implementing IoT-based SCM. This understanding will be beneficial to managers, industry practitioners, and researchers.

3.7. IoT based SCM challenges

- Consumer demand for products with complex patterns
  Due to factors including shifting consumer preferences, tastes, and technological advancements, the demand for items varies. As a result, the company faces challenges regarding product demand and supply. Therefore, it is difficult to predict the demand for products. The cutting-edge technologies of AI, Machine Learning, and Deep Learning may be used to overcome these limitations and challenges to predict consumer demand in IoT-based supply chain management. Authors in [42] used backorders historical data to predict the demand for particular products. The bullwhip effect is also observed as one of the challenging phenomena in SCM. This phenomenon illustrates the instability and variations in product and supplier orders at various points in the supply chain due to a lack of communication and coordination among various supply chain stages. It results in either frequent or infrequent purchases of supplies. It causes out-of-stock or backorder situations or compels businesses to lower their pricing. Authors in [49] proposed a cloud and 5G internet technology-based solution for a collaborative inventory management and information sharing system. Authors in [48] addressed the issue of product supply shortage using AI and RFID technology. The authors developed an Intelligent agent-based prediction system that will show product recommendations to the customers based on real-time data of product shelves and suggest customer products on hot sales. It will also notify sales support about out-of-stock products to help them with inventory replenishment.
- Cybersecurity risks associated with IoT-based supply chains
  There is a combination of physical and digital systems when using IoT-based SCM. This increases the level of cybersecurity risks. Organizational system vulnerabilities and operational machine-level vulnerabilities are anticipated by many connected devices and machines in a single IoT network. This happens due to a lack of integration of IoT infrastructure according to global standards and data-sharing protocols.
- High investment cost of building IoT infrastructure in SCM
  One of the major barriers to transitioning from traditional SCM to IoT-based infrastructure is high investment costs. When creating an IoT-based SCM infrastructure, businesses need to set up the necessary resources, network devices, sensors, and a team of skilled staff to run it. All these things require high investment costs, which can be expensive for small businesses.
- Network gaps
  The network infrastructure for SCM based on IoT is still not widespread. As SCM processes are geographically dispersed and require continuous information flow and real-time traceability, this is one of the challenges for IoT-based SCM. These requirements can only be met with a very powerful network infrastructure. Given that they offer low latency and quick data transfer via the internet, 4G networks are advantageous for IoT-based SCM. With 5G networks, this may be further enhanced as they offer extremely low latency and are quicker for real-time data transfer, which is necessary for SCM processes. Researchers in [49] implemented a Supply Chain Inventory Collaborative Management and Information Sharing system using RFID, cloud, and 5G internet technology to share real-time information on products at different stages of supply chain operations among stakeholders.
- Centralized system for data handling
  For managing data related to supply chain activities, individual firms employ a centralized system. Regarding Global Supply Chain Management (GSCM), these centralized systems fail to provide real-time data and, at some content, guarantee to hold some discrepancies in coordinating with other systems globally. However, these discrepancies in supply chain operations data can allow counterfeiters to tamper with data for their own benefit. Centralized data handling is not suitable, especially for GSCM. For this, there is a need for decentralized data handling, which can be possible by implementing Blockchain-based

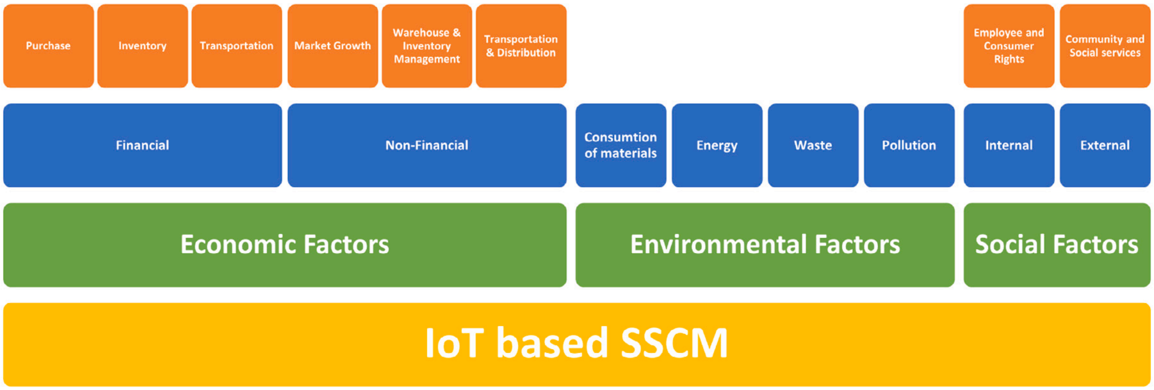

Fig. 12. Hierarchical framework for IoT base SSCM.

solutions in IoT-based SCM for handling supply chain operations data. Blockchain technology uses different cryptographic algorithms, smart contracts, and consensus mechanisms, enabling Peer Data Management (PDM) to serve trust among organizations and transparent supply chain operations data traceability.

- Lack of skilled staff
  Skills shortage is one of the top barriers to implementing IoT-based SCM in business. Access to the necessary skill set is required for IoT-based SCM to continue to succeed. Businesses will continue to struggle to make the greatest use of the data they collect from supply chain operations, integrate IoT initiatives into larger organizations, and reap the benefits of the revolutionary potential of IoT-based SCM. Organizations must seek professional training for IoT skills from external partners if they cannot fill these IoT skill gaps in-house.

3.8. Benefits of IoT based SCM

- Using IoT, a Sustainable Supply Chain Management (SSCM).
  While the traditional approaches to supply chain management focused primarily on the effectiveness, affordability, and ease of supply chain operations. In 2008, the concept of Sustainable Supply Chain (SSCM) was introduced by [54,55]. These researchers assert that SSCM blends sustainability's economic, environmental, and social facets. Utilizing IoT in the SCM process aids in sustainability, making it possible to produce high-quality goods using economical and environmentally beneficial techniques. SSCM is defined not just in economic and environmental terms but also in terms of the social aspects because it is built on the triple bottom line approach that encompasses people-planet-profit [56]. Fig. 12 proposes a hierarchical framework for IoT-based SSCM. According to this framework, three main factors, i.e., Economic, Environmental, and Social, serve as the foundations for achieving sustainability in the supply chain process. By considering these factors in IoT-based SCM, organizations can achieve sustainability. Economic factors include long-term financial and non-financial perspectives to work on. Financial perspectives include activities of the supply chain such as purchase, inventory, and transportation, whereas non-financial perspectives include activities such as market growth, warehouse & inventory management, and transportation & distribution. Organizations should consider green practices from both financial and non-financial perspectives to achieve economic sustainability. Environmental factors include activities to be considered, like consumption of materials, energy, waste, and pollution. Organizations must ensure sustainable actions to achieve environmental sustainability by producing products using minimal resources, utilizing energy efficiently, and reducing pollution by disposing of waste appropriately so that IoT-based SCM operations are environmentally friendly. Social factors are also important to be considered for achieving social sustainability. This includes perspectives that can be internal to the organizations, such as employee and customer rights, that must be preserved. External factors include community and social services. When running supply chain operations and designing products, organizations should consider its impacts on producing healthy, livable communities. In this way, organizations will also achieve social sustainability. When all three factors are considered, an IoT-based SSCM will be produced.
  - Enhanced transportation capacity, recycling and reusing packaging, decreased resource consumption (water and energy), and adherence to environmental regulations, e.g., green practices for SSCM. From raw material purchase (green purchasing) to manufacturing (eco-friendly design), retailing, and distribution can motivate adopting SSCM. Author in [46] used Blockchain technology along with IoT and RFID technologies to trace the products, which helped to achieve environmental sustainability by monitoring in real-time the products about their temperature or environmental conditions specifically in the case of the food supply chain to avoid food safety issues which can be food spoilage, food-borne diseases. This study also helped identify counterfeit foods as a threat to public health. For social sustainability, transparency in the system enables the monitoring of products from the point of origin to the ultimate customer. Trust is the main requirement for social sustainability. A transparent supply chain creates trust among business customers,

which helps achieve social sustainability. Overall proposed system provided ways for fast product deliveries and real-time monitoring of supply chain operations with reduced time of controlling processes.

- Lowering environmental risks
  IoT helps to achieve sustainability by lowering environmental risks. Environmental concerns and climate change may make the supply chain management process susceptible. Smart supply chain management processes are powered by IoT, and other IoT-enabling technologies like AI help to reduce these environmental risks. While products are being distributed, automated drones may be employed to monitor traffic, and other IoT sensors can be utilized to monitor environmental degradation throughout the supply chain process. One research identified in the systematic review presented an innovative solution to monitor occupational safety hazards at cold supply chains [13] as inadequate risk assessment and management might lead to cold-related accidents, injuries, and even fatalities. Researchers proposed establishing an IoT-based environment at cold supply chains so that workers engaged in demanding conditions may be better monitored in real-time using IoT sensors. Workers at cold supply chains were required to wear Microsoft bands, which allowed for monitoring their physical health. Other essential sensors were also employed to gather real-time data on the temperature of various cold supply chains. IoTRMS, a web-based tool, was developed to track occupational safety concerns.
- Focus on Circular Economy
  IoT-based supply chain management also focuses on a circular economy. A circular economy is a business idea that seeks to solve the world's economic issues by producing sustainable goods that are environmentally friendly and economically viable through resource management and reuse. It employs techniques for managing resources, waste, and energy. Using circular economy concepts transforms IoT-based supply chain management into sustainable IoT-based supply chain management. In addition, the idea of "circular supply chains" has evolved, with the goal of recycling goods that customers return to businesses [19]. Companies may improve their supply chains by using the data provided by IoT devices, which enables them to cut waste and allocate resources more effectively. IoT, for instance, may assist businesses in optimizing inventory levels, automating replenishment, and improving supply chain visibility.

• Continuous collaboration among stakeholders
  Utilizing IoT-based SCM makes collaborating with your production team, vendors, finance, regulatory, and logistics departments simple because IoT-based SCM offers simple solutions for traceability across the whole SCM process. Real-time data sharing with all stakeholders is simple when IoT and cloud-based technologies are used in the SCM process. When all stakeholders receive reports produced by evaluating real-time data gathered from IoT devices using big data analytics, this also enhances decision-making.
• Enhanced transparency and security throughout the product life cycle
  IoT and Blockchain have improved the transparency and verifiability of the product throughout its life cycle. From raw materials to manufacturing, distribution, and retailing, products may be monitored and traced at every stage of the supply chain process. Many research studies found in this SLR, such as [22–24], proposed IoT and Blockchain-based solutions for a secure and transparent supply chain management. This also helps to identify counterfeited products.
• Smart warehousing, distribution, and retailing of products
  IoT sensors aid the management of warehouses. Autonomous Mobile Robots (AMR) assist in moving products within the warehouse and towards the intended shipments. With IoT-based SCM, the effectiveness of the cargo and shipments employed in the supply chain for product distribution has enhanced. Shipping is now monitored using GPS technology [53]. The ability of IoT-based sensors and smart tags allows for the tracking and tracing of not only shipments but also goods. Packages using NFC, RFID, and DL-Tags (Distributed Ledger)-Tags [16] may readily share product information with stakeholders since these technologies are machine-readable, more secure, and transparent. The consumer experience has improved due to adopting IoT-enabled devices in retail. Nowadays, shelves include AI agents that can provide customers with real-time information about the lifespan of products, particularly perishable food items, frozen food, and medications stored in ideal temperatures. To guarantee everyone a high level of food safety throughout the traceability of the food supply chain, authors in [52] suggested a Blockchain and IoT-based food safety supply chain system that would allow customers to verify food products before purchasing them and only accept certified receipts.
• Reduction in scams and code of conduct violations
  Removing counterfeit items from the supply chain is a priority for manufacturers, distributors, shippers, and governmental organizations. In traditional SCM, it was very difficult to detect fake products. With IoT-based SCM use of smart tags makes the whole supply chain process more transparent and traceable. Many studies found in the literature use digital was to reduce product scams. The use of QR codes, RFID tags, NFC chips, DL-tags [16] and Blockchain technology [17] makes it possible to provide foolproof authenticity methods. Scanning of products using these smart tags can be performed by both retailers as well as by consumers. Authors in [44] used Ethereum technology to generate a secure QR code for the vehicle verification process.

3.9. Economic implications of implementing IoT-based SCM

IoT-based SCM helps businesses grow as IoT-based SCM provides best practices to automate the whole process of SCM. This increases the overall organization's performance to compete with other businesses. Its main goal is to promote the Circular Economy

(CE). IoT-based SCM solutions are economically viable for businesses, including the operations' feasibility and the potential for long-term circular value creation. Businesses benefit from using IoT-based SCM by spending less on purchasing raw materials and creating new products. The same applies to consumers who get high-quality products and services at lower prices. IoT can open up new business prospects in several SCM application sectors, including smart agriculture, smart logistics, warehouse management [53], energy, waste management, automotive, and wearable technology. This might result in the establishment of fresh firms and the production of new jobs, which would benefit the national economy. IoT-based SCM is the main driving force behind adopting the Circular Economy (CE). Concepts of additive manufacturing, asset utilization, reuse, repair, and recycling of components, existing materials and products, energy, resources, and waste management emerged due to the incorporation of IoT in SCM.

3.10. Business implications of implementing IoT-based SCM

Using sensors, devices, and smart tags, businesses can obtain real-time data on various supply chain processes, such as inventory levels, equipment performance, temperature conditions, and energy usage. With IoT, it is now easy for businesses to track shipments, which helps businesses in timely order fulfillment. This also aids in transparency in supply chain operations, which will help businesses in better warehouse and inventory management. Businesses empowered by IoT can now provide their customers with personalized customer experience. Businesses get useful insights about customer usage patterns and preferences by embedding IoT devices, sensors, and intelligent programs in their products. This enables customized product suggestions, focused market initiatives, and improved customer experience. The customer's overall experience can be further increased by IoT-enabled devices, providing customers with real-time monitoring and remote control options. IoT also helps predictive maintenance and asset management [20]. Businesses can track performance, detect anomalies, and identify maintenance requirements by gathering data from IoT sensors built into assets and machinery equipment. Businesses, by taking preventive measures, may avoid unplanned downtime. It also lowers repair time and cost and increases asset longevity. IoT enables remote monitoring so organizations can manage and optimize their assets across several locations.

4. Conclusion

Traditional SCM suffered many issues, including less transparent supply chain processes and difficulties in real-time monitoring of goods. It also includes challenges like counterfeited products due to a lack of transparency in the supply chain process. IoT-based SCM is an emerging practice to modernize the traditional SCM process using IoT. Modern SCM is more transparent because there is no issue with tracking products. It is also easy to record the products from purchasing raw materials, manufacturing, and distribution. A gap was found in the literature that no comprehensive SLR was present. This paper presented the first SLR on IoT-based SCM, comprehensively analyzing literature in the past five years. This study contributes to the knowledge of IoT-based SCM by covering the main areas of the topic, like application domains, technologies, sensors, and devices used to implement such systems. The SLR findings are exciting and valuable and can help future researchers get a quick review of IoT-based SCM. This review reveals that not only IoT but IoT-enabling technologies like AI, Blockchain, and Cloud computing are newly introduced in this domain and can be further explored to make IoT-based SCM more robust. This review also gives a clear picture of the application domains. Most research is done on the Agri-Food supply chain and the Medical and Healthcare supply chain, and few works have been done on the Industrial and Manufacturing supply chain. Industrial and manufacturing supply chains can be further explored as future researchers focus on Industry 4.0 and Industry 5.0 [51], so this would be a good application domain for IoT-based SCM. Businesses are also focusing more on acquiring and providing goods and services in a way that lessens their negative effects on the environment, society, and economy. In light of the aforementioned, the idea of Sustainable Supply Chain Management (SSCM) has attracted the interest of both business and academia due to its emphasis on corporate responsibility in terms of the environment, society, and the economy. Research on SSCM is also a promising research direction to work on for achieving sustainability when employing IoT-based SCM.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

[1] K. Ashton, et al., That 'internet of things' thing, RFID J. 22 (7) (2009) 97–114.
[2] E. Borgia, The internet of things vision: Key features, applications and open issues, Comput. Commun. 54 (2014) 1–31.
[3] S.A. Al-Qaseemi, H.A. Almulhim, M.F. Almulhim, S.R. Chaudhry, IoT architecture challenges and issues: Lack of standardization, in: 2016 Future Technologies Conference, FTC, IEEE, 2016, pp. 731–738.
[4] SCM Definitions and Glossary of Terms, Cscmp.org, 2018, URL https://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx?hkey=60879588-f65f-4ab5-8c4b-6878815ef921.
[5] M. Abdel-Basset, G. Manogaran, M. Mohamed, Internet of things (IoT) and its impact on supply chain: A framework for building smart, secure and efficient systems, Future Gener. Comput. Syst. 86 (9) (2018) 614–628.

[6] M. Ben-Daya, E. Hassini, Z. Bahroun, Internet of things and supply chain management: a literature review, Int. J. Prod. Res. 57 (15–16) (2019) 4719–4742.
[7] A. Rejeb, S. Simske, K. Rejeb, H. Treiblmaier, S. Zailani, Internet of things research in supply chain management and logistics: A bibliometric analysis, Internet Things 12 (2020) 100318.
[8] R.M.L. Rebelo, S.C.F. Pereira, M.M. Queiroz, The interplay between the internet of things and supply chain management: Challenges and opportunities based on a systematic literature review, Benchmarking: Int. J. 29 (2) (2022) 683–711.
[9] M. Hussain, W. Javed, O. Hakeem, A. Yousafzai, A. Younas, M.J. Awan, H. Nobanee, A.M. Zain, Blockchain-based IoT devices in supply chain management: a systematic literature review, Sustainability 13 (24) (2021) 13646.
[10] B. Kitchenham, Procedures for Performing Systematic Reviews, Vol. 33, No. 2004, Keele University, Keele, UK, 2004, pp. 1–26.
[11] M.J. Page, J.E. McKenzie, P.M. Bossuyt, I. Boutron, T.C. Hoffmann, C.D. Mulrow, L. Shamseer, J.M. Tetzlaff, E.A. Akl, S.E. Brennan, et al., The PRISMA 2020 statement: an updated guideline for reporting systematic reviews, Int. J. Surg. 88 (2021) 105906.
[12] M. Sangeetha, Smart supply chain management using internet of things, Int. J. Syst. Control Commun. 9 (2) (2018) 172–184.
[13] Y.P. Tsang, K.L. Choy, C.-H. Wu, G.T. Ho, C.H. Lam, P. Koo, An internet of things (IoT)-based risk monitoring system for managing cold supply chain risks, Ind. Manag. Data Syst. 118 (7) (2018) 1432–1462.
[14] C. Verdouw, R.M. Robbemond, T. Verwaart, J. Wolfert, A.J. Beulens, A reference architecture for IoT-based logistic information systems in agri-food supply chains, Enterp. Inf. Syst. 12 (7) (2018) 755–779.
[15] W. Zhou, S. Piramuthu, IoT security perspective of a flexible healthcare supply chain, Inf. Technol. Manag. 19 (2018) 141–153.
[16] F.M. Benčić, P. Skočir, I.P. Žarko, DL-Tags: DLT and smart tags for decentralized, privacy-preserving, and verifiable supply chain management, IEEE Access 7 (2019) 46198–46209.
[17] P. Cui, J. Dixon, U. Guin, D. Dimase, A blockchain-based framework for supply chain provenance, IEEE Access 7 (2019) 157113–157125.
[18] H. Fan, Theoretical basis and system establishment of China food safety intelligent supervision in the perspective of internet of things, IEEE Access 7 (2019) 71686–71695.
[19] C. Garrido-Hidalgo, T. Olivares, F.J. Ramirez, L. Roda-Sanchez, An end-to-end internet of things solution for reverse supply chain management in industry 4.0, Comput. Ind. 112 (2019) 103127.
[20] W. Kuandee, P. Nilsook, P. Wannapiroon, Asset supply chain management system-based IoT technology for higher education institutions., Int. J. Online & Biomed. Eng. 15 (3) (2019).
[21] K. Leng, L. Jin, W. Shi, I. Van Nieuwenhuyse, Research on agricultural products supply chain inspection system based on internet of things, Cluster Comput. 22 (2019) 8919–8927.
[22] Q. Lin, H. Wang, X. Pei, J. Wang, Food safety traceability system based on blockchain and EPCIS, IEEE Access 7 (2019) 20698–20707.
[23] A. Maiti, A. Raza, B.H. Kang, L. Hardy, Estimating service quality in industrial internet-of-things monitoring applications with blockchain, IEEE Access 7 (2019) 155489–155503.
[24] S. Mondal, K.P. Wijewardena, S. Karuppuswami, N. Kriti, D. Kumar, P. Chahal, Blockchain inspired RFID-based information architecture for food supply chain, IEEE Internet Things J. 6 (3) (2019) 5803–5813.
[25] N. Mostafa, W. Hamdy, H. Alawady, Impacts of internet of things on supply chains: a framework for warehousing, Soc. Sci. 8 (3) (2019) 84.
[26] A.-S. Oh, Development of a smart supply-chain management solution based on logistics standards utilizing artificial intelligence and the internet of things, J. Inf. Commun. Converg. Eng. 17 (3) (2019) 198–204.
[27] Y.P. Tsang, K.L. Choy, C.H. Wu, G.T.S. Ho, H.Y. Lam, Blockchain-driven IoT for food traceability with an integrated consensus mechanism, IEEE Access 7 (2019) 129000–129017.
[28] R. Wang, C. Yu, J. Wang, Construction of supply chain financial risk management mode based on internet of things, IEEE Access 7 (2019) 110323–110332.
[29] S. Wang, D. Li, Y. Zhang, J. Chen, Smart contract-based product traceability system in the supply chain scenario, IEEE Access 7 (2019) 115122–115133.
[30] N. Alkaabi, K. Salah, R. Jayaraman, J. Arshad, M. Omar, et al., Blockchain-based traceability and management for additive manufacturing, IEEE Access 8 (2020) 188363–188377.
[31] Q. Gao, S. Guo, X. Liu, G. Manogaran, N. Chilamkurti, S. Kadry, Simulation analysis of supply chain risk management system based on IoT information platform, Enterp. Inf. Syst. 14 (9–10) (2020) 1354–1378.
[32] C. Jun, Research on simulation of school uniform supply chain optimal model based on internet of things, EURASIP J. Wireless Commun. Networking 2020 (1) (2020) 1–15.
[33] J. Muñuzuri, L. Onieva, P. Cortés, J. Guadix, Using IoT data and applications to improve port-based intermodal supply chains, Comput. Ind. Eng. 139 (2020) 105668.
[34] M. Safkhani, S. Rostampour, Y. Bendavid, N. Bagheri, IoT in medical & pharmaceutical: Designing lightweight RFID security protocols for ensuring supply chain integrity, Comput. Netw. 181 (2020) 107558.
[35] A. Sourav, N. Lynn, S. Suyoto, Smart monitoring system design for perishable food supply chain management based on IoT in Bangladesh, Int. J. Adv. Sci. Technol. 29 (1) (2020) 1069–1079.
[36] S. Yadav, D. Garg, S. Luthra, Development of IoT-based data-driven agriculture supply chain performance measurement framework, J. Enterp. Inf. Manag. 34 (1) (2021) 292–327.
[37] W. Alkhader, K. Salah, A. Sleptchenko, R. Jayaraman, I. Yaqoob, M. Omar, Blockchain-based decentralized digital manufacturing and supply for COVID-19 medical devices and supplies, IEEE Access 9 (2021) 137923–137940.
[38] O. Alkhoori, A. Hassan, O. Almansoori, M. Debe, K. Salah, R. Jayaraman, J. Arshad, M.H.U. Rehman, Design and implementation of CryptoCargo: A blockchain-powered smart shipping container for vaccine distribution, IEEE Access 9 (2021) 53786–53803.
[39] B. Almadani, S.M. Mostafa, IIoT-based multimodal communication model for agriculture and agro-industries, IEEE Access 9 (2021) 10070–10088.
[40] M.S. Al-Rakhami, M. Al-Mashari, A blockchain-based trust model for the internet of things supply chain management, Sensors 21 (5) (2021) 1759.
[41] S. Awan, S. Ahmed, F. Ullah, A. Nawaz, A. Khan, M.I. Uddin, A. Alharbi, W. Alosaimi, H. Alyami, IoT with blockchain: A futuristic approach in agriculture and food supply chain, Wirel. Commun. Mob. Comput. 2021 (2021) 1–14.
[42] M.N.M. Bhutta, M. Ahmad, Secure identification, traceability and real-time tracking of agricultural food supply during transportation using internet of things, IEEE Access 9 (2021) 65660–65675.
[43] L. Cocco, K. Mannaro, R. Tonelli, L. Mariani, M.B. Lodi, A. Melis, M. Simone, A. Fanti, A blockchain-based traceability system in agri-food SME: Case study of a traditional bakery, IEEE Access 9 (2021) 62899–62915.
[44] G. Subramanian, A.S. Thampy, Implementation of hybrid blockchain in a pre-owned electric vehicle supply chain, IEEE Access 9 (2021) 82435–82454.
[45] G. Subramanian, A.S. Thampy, N.V. Ugwuoke, B. Ramnani, Crypto pharmacy–digital medicine: A mobile application integrated with hybrid blockchain to tackle the issues in pharma supply chain, IEEE Open J. Comput. Soc. 2 (2021) 26–37.
[46] V. Varriale, A. Cammarano, F. Michelino, M. Caputo, Sustainable supply chains with blockchain, IoT and RFID: A simulation on order management, Sustainability 13 (11) (2021) 6372.
[47] M. Wu, Optimization of E-commerce supply chain management process based on internet of things technology, Complexity 2021 (2021) 1–12.
[48] W. Yang, Y. Chen, Y.-C. Chen, K.-C. Yeh, Intelligent agent-based predict system with cloud computing for enterprise service platform in IoT environment, IEEE Access 9 (2021) 11843–11871.
[49] F. Zhang, Z. Gong, Supply chain inventory collaborative management and information sharing mechanism based on cloud computing and 5G internet of things, Math. Probl. Eng. 2021 (2021) 1–12.

[50] X.N. Zhu, G. Peko, D. Sundaram, S. Piramuthu, Blockchain-based agile supply chain framework with IoT, Inf. Syst. Front. (2021) 1–16.
[51] M.S. Al-Rakhami, M. Al-Mashari, ProChain: provenance-aware traceability framework for IoT-based supply chain systems, IEEE Access 10 (2021) 3631–3642.
[52] S. Balamurugan, A. Ayyasamy, K.S. Joseph, IoT-blockchain driven traceability techniques for improved safety measures in food supply chain, Int. J. Inf. Technol. (2021) 1–12.
[53] A. Bhargava, D. Bhargava, P.N. Kumar, G.S. Sajja, S. Ray, Industrial IoT and AI implementation in vehicular logistics and supply chain management for vehicle mediated transportation systems, Int. J. Syst. Assur. Eng. Manag. 13 (Suppl 1) (2022) 673–680.
[54] C.R. Carter, D.S. Rogers, A framework of sustainable supply chain management: moving toward new theory, Int. J. Phys. Distrib. Logist. Manag. 38 (5) (2008) 360–387.
[55] S. Seuring, M. Müller, From a literature review to a conceptual framework for sustainable supply chain management, J. Clean. Prod. 16 (15) (2008) 1699–1710.
[56] R. Baliga, R.D. Raut, S.S. Kamble, Sustainable supply chain management practices and performance: An integrated perspective from a developing economy, Manag. Environ. Qual. Int. J. 31 (5) (2020) 1147–1182.