Comprehensive review:

Enhancing Food supply chain management through Big Data technologies and strategies

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Abstract

Purpose – This paper explores the enhancement of Food Supply Chain Management (FSCM) through Big Data Technologies and Strategies. It assesses current key challenges, identifies areas of underutilization, and evaluates technology advancements aimed at optimizing the existing Food Supply Chain.

Design/Methodology – The systematic literature review analyzed 324 documents indexed in Scopus, Web of Science, and Google Scholar. The review covers peer- reviewed articles, published between 2015 to 2024. Selecting these sources helps to understand diverse challenges in the industry and a reasonable timeframe helps in capturing the evolution and recent advancements. The selection criteria include relevance to the Big Data applications, industry challenges, and technical advancements where the keywords are related to Big Data and Food Supply Chain (FSC) that guided the research and then were screened for quality and relevance. Data extraction focused on key themes such as technologies used, benefits observed, and challenges identified. The goal was to capture a holistic view of the research landscape and identify gaps and future opportunities.

Findings – The review highlights increased scholarly attention on Big Data in FSCM, using technologies such as Data analytics, Machine Learning, Artificial Intelligence, Blockchain, Internet of Things (IoT), and Smart Agriculture to improve traceability, efficiency, and sustainability. The identified gaps include regional concentration of studies and limited adoption of technologies by Small and Medium Enterprises (SMEs). The study addresses these gaps and provides guidance to apply new technology, minimize food wastage and improve food quality at each stage of the Food Supply Chain process.

Practical implications – This research underscores the disparity in the adoption of these technologies between large and SMEs, particularly due to resources constraints. Large firms typically have better access to the expertise and infrastructure necessary for deploying Big Data solutions effectively. Despite these limitations, the review identified the current gap and offered actionable recommendations for implementing effective Big Data strategies in the industry.

Social Implications – The focus of studies to specific countries/regions limits the analysis of the global Food Supply Chain due to restrictions to fully capture the challenges and opportunities in developing regions and their applicability to diverse socioeconomic contexts. However, understanding Big Data adoption in the (Food Supply Chain) FSC Management, will contribute in significant reductions in food wastage. This can support farmers to grow crops and improve export accessibility in global regions.

Originality/value – This study reviews existing literature on Big Data applications in the Food Supply Chain. It identifies benefits, challenges, implementation frameworks and future research opportunities. Its unique contribution lies in highlighting gaps, such as selection of tools and techniques for using Big Data and managing food wastage by applying these tools at each phase of the supply chain. Future research should address these gaps by exploring inclusive strategies for technology adoption in SMEs and conducting globally representative studies. This review serves as a valuable resource for both academics and practitioners, guiding future research and implementation efforts for an efficient FSCM.

Keywords – *Big Data, Blockchain, Food security, Food Supply Chain Management, Internet of Things, Predictive analytics, supply chain optimization, sustainability and Systematic literature review.*

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Abbreviations

AI	Artificial Intelligence
B2B	Business to Business
FSC	Food Supply Chain
FSCM	Food Supply Chain Management
GPS	Global Navigation Satellite System
ICT	Information and Communication Technology
IoT	Internet of Things
Power BI	Power Business Intelligence
QR	Quick Response
RFID	Radio frequency identification detector
RQ	Research Questions
SME	Small and Medium Enterprises
SLR	Systematic Literature Review

Introduction

In the rapidly evolving food industry, successful arrangement of the supply chain in Food industry is getting tougher day by day (Rejeb et al., 2022). As the complexities are growing with the scale of operations, traditional manual methods are proving inadequate. These methods often fail to give the real-time, accurate data needed to make informed decisions in the face of globalization, increasing consumer demands and sustainability challenges. World's economy is changing quickly, and as a new entrant have been part of the market, they understand that the largest profit does not lie in manufacturing but rather it is in distribution (Navickas, & Gruzauskas, 2016). For this, a new perspective is required in FSCM which is obtained through the Big Data analytics. Consequently, organizations are turning into big data technologies and strategies, particularly big data analytics to improvise their current decision-making process and optimize supply chain operations (Navickas, & Gruzauskas, 2016).

The large volume, Velocity and variety of Big Data makes it a valuable tool for improving Food Supply Chain Management (Tao et al., 2015). By utilizing Big Data, organizations can get important insights into market trends, optimize inventory levels, improve demand forecasting, and support in maintaining quality of the food products. Despite growing interest in applications of Big Data in FSCM, this sector remains fragmented and lacks overall comprehensive analysis of the current literature (Tao et al., 2015).

As the FSCM landscape evolves, the adoption of advanced technologies through Big Data has become essential for navigating organizational challenges. The data obtained through the Food Supply Chain presents an opportunity for processing and analyzing this information from various sources. Organizations can identify new possibilities and optimize supply chain activities by integrating historical data with real time market information with the use of data analytics in the FSCM (Tao et al., 2015). The objective of this assessment of the literature is to classify the current research trends and suggest a conceptual framework for FSCM Big Data applications. Therefore, this research aims to close the fragmentation gap and enhance relationship between FSC performance and Big Data applications.

Problem Statement

The problem statement in the research report is as follows:

- The Food Supply Chain supports the basic needs of humankind, and they are vital in the global economy. With the growing challenges, this industry faces more complexities, demand and scalability issues to have sustainability.
- The traditional method is now not sufficient to handle the huge sets of data captured by modern systems.
- The changing economic landscape has shifted the focus from manufacturing to distribution which has increased the pressure on the supply chain
- The growing food sector has immense data collection, but very little research has been made on the selection of appropriate technology to leverage output from it.
- The organization's capacity to effectively utilize Big Data technologies to improve decision making, streamline operations, and solve important concerns like food safety, waste reduction, and demand forecasting is limited by the lack of a framework for doing so in FSCM.

Research strategies for addressing the challenges in Big Data technologies within Food supply chain industry

In order to solve the issues that have been highlighted, a comprehensive literature review that compiles the body of knowledge on the use of big data in the food supply chain is conducted. In doing so, it will be able to compile the data and discover important trends, technologies, and tactics used at various points in the food supply chain.

- **Identify Gaps and opportunities**

  This research reveals the areas where Big Data has been underutilized or inconsistently applied, mainly in emerging technologies such as blockchain, machine learning, and the Internet of Things. This research also provides direction for future studies and practical applications of these technologies giving a holistic approach to FSCM.

- **Proposing a guidance**

  This research provides conceptual guidance that the organization can adopt to systematically implement Big Data technologies across the supply chain. It also guides on traceability, efficiency and sustainability thereby addressing the critical pain points identified in the problem statement.

- **Enhancing global relevance**

  This study clarifies the requirement to broaden the geographic scope of research, proposing strategies for applying Big Data Technologies in both developed and developing regions.

These global perspectives ensure that the findings are applicable across diverse socioeconomic contexts, making the research relevant to a wider audience.

- **Provide Practical Recommendation**

  By analyzing case studies and current practices, this research offers actionable insights for industry practitioners. The recommendations given are aimed at overcoming barriers to technology adoption, such as cost and expertise limitations, particularly for small and medium enterprises.

Research Questions (RQ)

RQ1) What are Big Data applications, technologies and strategies currently available for improving supply chain management?

RQ2) How can Big Data technologies and strategies be applied to different stages of the supply chain?

Materials and Methods

The techniques used for the Systematic Literature Review (SLR) on the use of big data analytics in food supply chain management (FSCM) are covered in this part. Finding and classifying the prevalent research themes, patterns, and gaps in the body of current literature is the aim. The SLR adheres to the identification, screening, eligibility, and inclusion framework. The research methodology includes multiple steps as presented in Figure 2 (Protopop, 2016):

The review focused on the examining the relationship between "Big Data" and "Food Supply Chain Management." The following search strings were employed by the author:

(“Food Supply Chain” OR “Food Logistics” OR “Food and Supply Chain Management” OR “Agro and Food Distribution” OR “Supply Chain Optimization”)

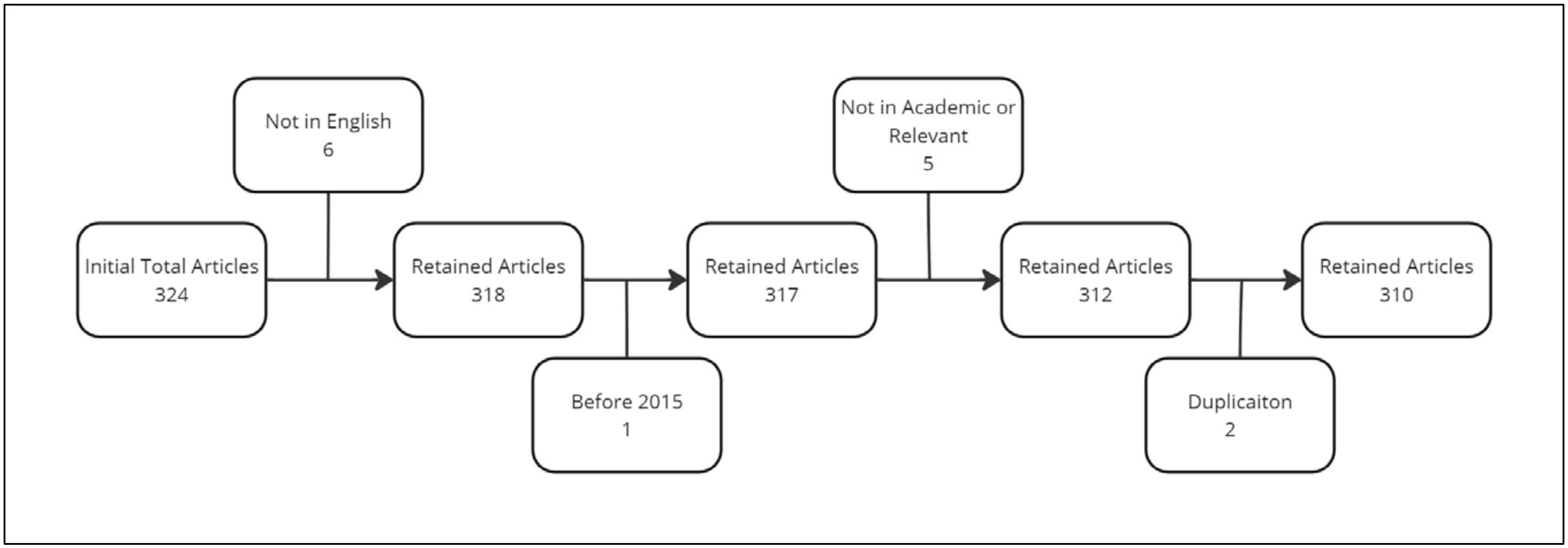
AND

(“Big Data” OR “Data Analytics” OR “Digital Transformation” OR “IoT” OR “Predictive Analytics”)

The author generated the idea of finding the greatest number of appropriate, relevant articles for this assessment based on the information provided above. 324 articles in all were found to meet our selection criteria. To provide a varied and thorough collection of sources, these articles were extracted from the databases Scopus, Web of Science and Google Scholar. These sources include conference papers and books that provide insightful information in addition to high-quality sources. The author kept papers published in English, from scholarly journals, and published after 2015 by applying the following exclusion criteria (Figure 1).

Figure 1

Process of Selection against the exclusion criteria



Selection of articles: Articles were selected based on relevance to big data applications in FSCM. Sources include Scopus, web of science, google scholar and Science Direct, focusing on peer reviewed documents published between 2015 and 2024.

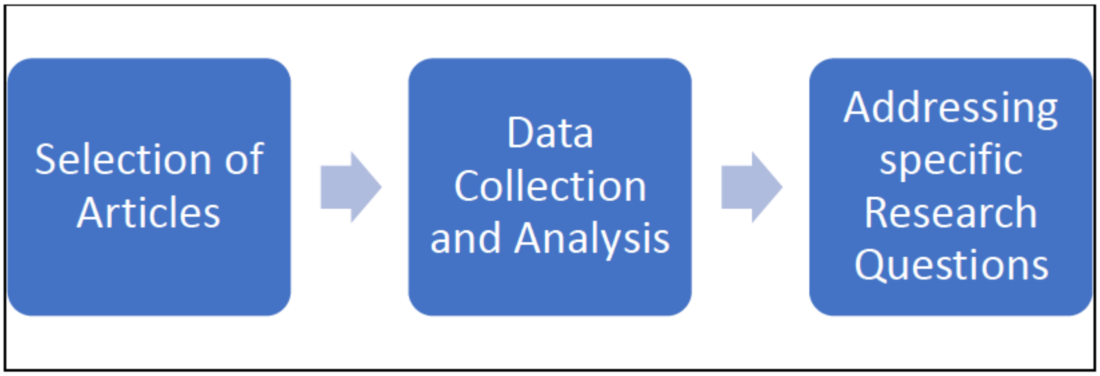
Data collection: Relevant articles were identified using specific keywords related to big data and food supply chains. The collected data included information on authors, titles, abstracts, keywords, journals and publication analysis.

Data analysis: The data was normalized to ensure consistency and accuracy. Key themes such as technologies used, benefits observed, and challenges identified were extracted. Network metrics (Zhao & Strotmann, 2015) were generated to analyze relationships between various elements like co-authorship, keyword occurrences and citation networks. This investigation focuses on the food supply chains related to agriculture, increasing their efficiency, controlling food quality, reducing food loss along the chain, and urban areas (Azevedo et al., 2021).

Addressing specific research questions: The collected and analyzed data aimed to answer specific research questions related to the patterns and efficiency of big data applications in FSCM.

Figure 2

Research methodology



To comprehend the current state of big data applications in the food supply chain, a thorough literature review was carried out in three phases.

- Phase I: Research design
- Phase II: Data synthesis
- Phase III: Data analysis

This review includes academic articles, industry reports, and case studies to identify methods for enhancing traceability and transparency, and developing data acquisition and assimilation capabilities (Shou, 2021). An in-depth analysis of case studies about other organizations who have successfully implemented these applications shall provide insights into the challenges and opportunities of these technologies. The gathered data was examined by statistical and qualitative methods of analysis (Tello, 1999) in order to address the study questions and formulate suggestions for companies planning to integrate big data into their food supply chain. To guarantee the validity and relevance of research findings, expert evaluations and feedback sessions were used to validate the conclusions and recommendations (Teng et al., 2022).

Phase I: Research Design

The research design comprises of two strategies. First, imperative keywords (Johnson, 2016) reflecting the wider scope of the research were used to explore the databases. Second, high level publication keywords such as “Big Data” and “Food Supply Chain” were employed, yielding a substantial amount of database results (Table 1).

Table 1

Related Keywords and strings used in Literature Review

Related Keywords used for Conducting Research
“Big Data”
“Food Supply Chain”
“Data Analytics”
“Food Logistics”
“Digital transformation”
“IoT”
“Predictive Analytics”
“Food Supply Chain Management”
“Agro Food Distribution”
Relates Strings Used for Conducting Research
“Big Data” AND Food Supply Chain” OR
“Food Logistics” AND “Data Analytics”
“Food Supply Chain” AND “Digital Transformation”
“Agro Food Distribution” AND “IoT”

“Predictive Analytics” AND “Food Supply Chain Management”
“Big Data” AND “Supply Chain Optimization”
“Big Data” AND “Technology” AND “Strategy” AND “Food Supply”

Table 2 lists the inclusion and exclusion criteria that were applied to this research study as per Kitchenham and Charters (Kitchenham and Charters, 2007).

Table 2

Research Papers – Inclusion and Exclusion Criteria

Inclusion Criteria	**Exclusion Criteria**
The writing style of the paper is English.	Written in a language other than English
Full text available Online	Physical hard copy text
Paper contains empirical data	Articles that don't collect actual data but have theoretical foundations
Paper written in between year 2015 - 2024	Paper outside of that date range
Peer-reviewed research papers, Article conference Paper, Book	Short survey, Retracted documents, Notes, letters, Editorials

Phase II: Data Synthesis

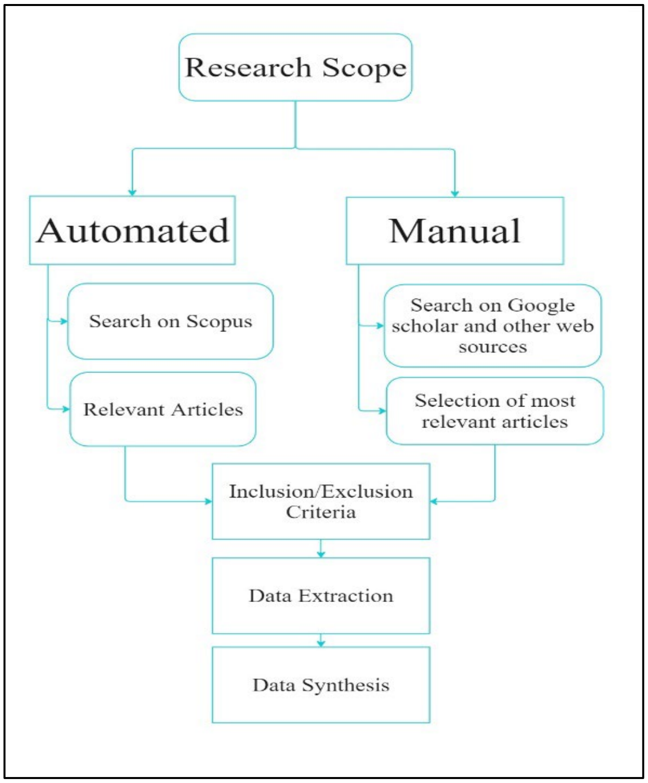
The data synthesis phase involves a rigorous and systematic process that begins with collecting research articles from various databases. The goals were to eliminate any publications that did not significantly advance the field of Big Data Applications in Food Supply Chain Management research (Han, 2018). Inclusion criteria focused on peer reviewed papers and articles with clear relevance to FSCM, while non peer reviewed papers and those lacking relevance were excluded (Patidar, 2022).

Both automatic and manual stages were followed in the data synthesis process. For the automatic stage, the Scopus database was utilized due to its concentration on high – impact journals and comprehensive information. To guarantee sufficient coverage of Big Data technologies in the Food Supply Chain, the keywords were carefully chosen. In contrast to conferences and published journals, electronic records offer a wider viewpoint on the subject at hand (Kitchenham and Charters, 2007).

The manual analysis involves examining the references of all selected materials and applying primary study references, ensuring thorough examination of all relevant articles (Figure 3).

Figure 3

Data Synthesis



The author used a combination of content and thematic analysis to assess the chosen articles (Margaritis et al., 2022). To find important themes, patterns, and insights on the usage of big data in FSCM, thematic analysis was employed. Content analysis was used to quantify the presence of certain keywords, themes or contexts. Both these approaches helped to reach an understanding of the relevant research landscape. Table 3 presents the research article classification according to its relevance to the topic of this literature evaluation.

Table 3

Research Article Statistics

Source	**Status**
Total Researched Articles	324

Extremely Relevant*	48
Medium Relevant	129
Less Relevant	133
Irrelevant	14

The author then studied all the 324 research papers from the Scopus database and categorized them into Highly relevant, Medium relevant, and less relevant (Dickersin et al., 1994)

Extremely Relevant*: These research papers provide critical insights directly aligned with our research objective. Out of 48 extremely relevant papers, 14 papers are included in the table below as a major reference because these paper's credibility is high and their methodological part is more rigorous, valid and reliable. The chosen papers have allowed author to have coherent and focused analysis for constructing a narrative and argument, relevance to author's central research question. Other relevant paper was reviewed and excluded from here due to either methodological limitation or less direct relevance to the present context. The analysis of extremely relevant articles has been listed below in Table 4:

Table 4

Extremely Relevant Papers

Main Topic	Summarization of Papers
"A Conceptual Framework: Big Data Applications in Food Supply Chain Management" – (Margaritis et al., 2022)	An overview of BD application trends is given in this study.

"Big Data Analytics in Logistics and Supply Chain Management" – (Ata et al., 2017)	An overview of big data applications in supply chain and logistics is given in this paper.
"Big Data in Food" – (Chakraborty et al., 2023)	The usage of big data applications in the food business is discussed in this study.
"Food Supply Chain Transformation through Technology and Future Research Directions" – (Abideen et al., 2021)	The use of technology to decrease waste, enhance food safety, and decrease the chances of a worldwide food crisis is the main topic of this study.
"Practitioners understanding of Big Data and its applications in supply chain management" – (Brinch et al., 2018)	This paper presents an overview of big data and looks at its uses from a business standpoint.
"Big Data in the Food Supply Chain" – (Rejeb et al., 2022)	The potential application of big data to the food supply chain is the main topic of this article.
"A study on decision-making of Food Supply Chain based on Big Data" – (Ji.et al., 2017)	The incorporation of technology into the food supply chain is the main topic of this essay.
"Big Data concept in the Food Supply Chain: small markets case" – (Navickas and Gruzauskas, 2016)	This case study aims to elucidate the technological disparity within the food supply chain.
"Big Data for sustainable agri-Food Supply Chain s: a review and future research perspectives" – (Rejeb et al., 2021)	The application of big data to smart farming is summed up in this study.

“Big Data for agri-food 4.0” – (Belaud et al., 2019)	Applications of big data technologies in agriculture are compiled in this study.
“Big Data in food safety” – (Jin et al., 2020)	The application of big data in food safety is the main topic of this essay.
“Big Data and smallholder farmers” – (Protopop et al., 2016)	The usage of big data applications in the developing world's agri-food supply chain is summed up in this study.
“Digital transformation in small and medium enterprises” – (Parra-Sánchez et al., 2024)	The use of digital transformation in small and medium-sized businesses is examined in this article.
“Data-driven capabilities, supply chain integration and competitive performance” – (Irfan and Wang, 2019)	This paper focuses on Big Data-driven capabilities in supply chain management.

Medium Relevant: Research papers in this category offered substantial yet indirect contributions to our study as they were essential in enriching our framework and providing contextual understanding.

Less Relevant: These studies contributed minimally to our analysis.

Irrelevant papers: The articles deemed irrelevant do not have a significant impact on our study. These papers emerged in our search due to overlapping keywords but were excluded as they did not contribute to our understanding of Big Data in FSCM.

A highly systematic and comprehensive methodology was employed for the examination of the papers to capture the multidimensional nature of design theory. The creation of bibliographic text and Excel files marked the end of the data synthesis process, preparing it for the data analysis.

Phase III: Data Analysis

The data analysis phase involved using a Bibliometrix tool based on the R programming language to generate a visual depiction of the study data (Aria and Cuccurullo, 2017). The author utilized Biblioshiny, a web-based interface that simplifies the bibliometric analysis process without requiring advanced programming skills.

Biblioshiny was particularly suitable for this study due to its capacity to effectively handle and evaluate substantial amounts of bibliographic data effectively, offering statistical analysis, visualization of options and handling large datasets. The bibliography includes statistical analysis, visualization options and the ability to handle a large dataset. However, limitations such as dependency on the quality of input data and potential difficulty in capturing the qualitative insights from that particular dataset were encountered in the analysis.

The use of Biblioshiny in this study has in total enabled a thorough and systematic literature review, revealing the critical insights into application of Big Data in Food Supply Chain Management. By fusing the strength of bibliometrics with conventional techniques, a well-rounded perspective could be generated in the research, guiding future investigations in the right direction.

The steps followed in the process include:

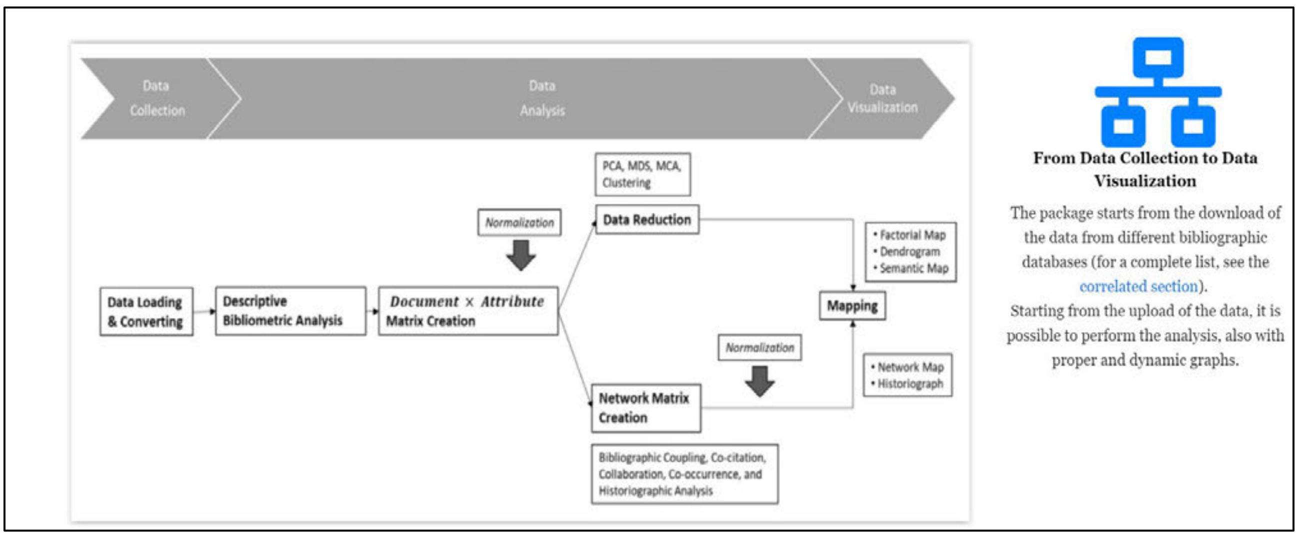
- The bibliometric file created during the data synthesis process was imported to Biblioshiny. The Bibtex file (.bib file) was uploaded to the Biblioshiny tool.
- Then another step involves tasks such as normalization, data reduction and the generation of network matrices to filter and extract critical information from the dataset (Bibliometrix website)

- Now the graphical representations such as trend analyses, maps, and other significant visual outputs are generated and visual analyses are performed including cumulative occurrence charts, word clouds, tree maps, and overview dashboard (Bibliometrix website).

Biblioshiny, part of the Bibliometrix package provides an intuitive interface for conducting bibliometric analysis, making it accessible for users who may not have extensive programming experience (Aria and Cuccurullo, 2017).

Figure 4

Biblioshiny Analysis using Bibliometrix tool



Note. Aria and Cuccurullo, 2017

Methods for Literature Review Analysis

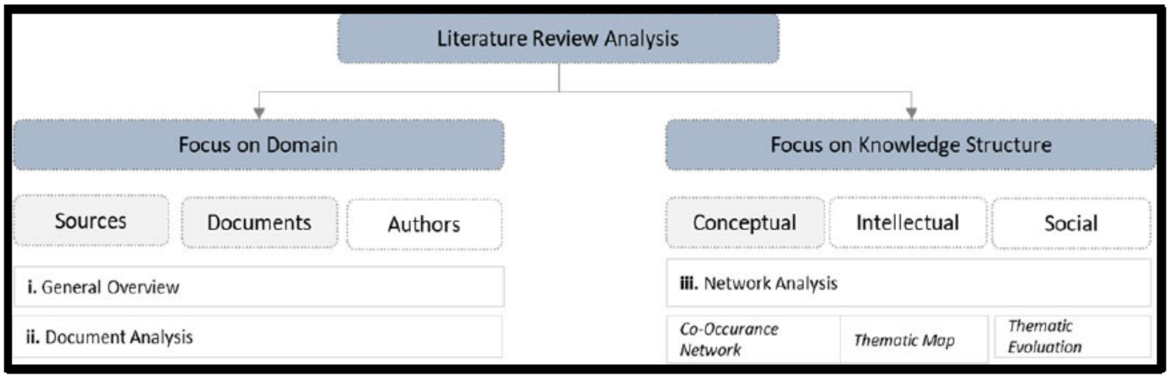
The bibliographic data collected from databases such as Scopus and Web of Science was exported in BibTex format for analysis. The analysis began by normalizing the data to ensure consistency and accuracy, involving removing duplicates and standardizing author names and keywords.

A key aspect of this analysis was the generation of network matrices to establish relationships between various elements such as co-authorship networks, keyword co-occurrences and citation networks (Aria, and Cuccurullo, 2017). Biblioshiny provided a range of visualization tools, including word clouds, thematic maps, and network visualization (Aria, and Cuccurullo, 2017) to create insightful graphical representations of data, visualize the growth of publications over time, and highlight trends and peaks in research activities.

The data analysis using Biblioshiny provided meaningful conclusions about Big Data technologies in FSCM, pinpointing research gaps, emerging trends, and influential studies associated to the application of Big Data technologies (Aria and Cuccurullo, 2017). The analysis was divided into two main focuses: domain-focused and knowledge-structure focused analysis (Figure 5). The domain focused analysis here concentrates on relevant sources such as journals, conference papers, other documents, sources and citations. The knowledge structure-focused analysis concentrates on conceptual, intellectual and social aspects presenting interlinks and connections on different topics through thematic maps, tree maps and network visualization. For example: the keyword co-occurrences helped to highlight the main topic and technologies being explored in the research.

Figure 5

Literature Review Analysis through Biblioshiny Tool for Bibliometric Analysis



Data Visualization

In the research analysis of enhancing Food Supply Chain through Big Data technologies, several tools were used for visualization purposes, as shown in Table 4.

Table 4

Visualization tool

Biblioshiny	Three field plot, word count, tree map, cumulative occurrence, trend chart
Bibliometrics	R programming
MIRO	Organizing themes, collaborative brainstorming, and project workflows
Tableau	Data visualization and creating infographics.
Excel	To obtain charts, graphs for data visualization

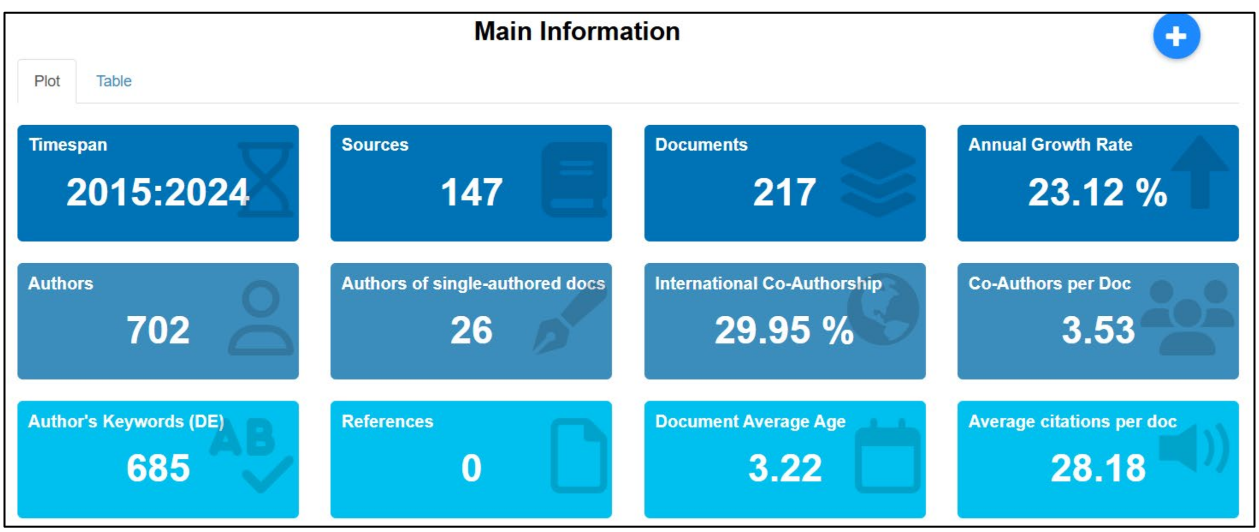
Data Interpretation

Various visualization tools provided meaningful data, offering detailed insights into the collected literature. This phase supported determining trends, themes, and gaps in the existing body of research. Biblioshiny software (Aria and Cuccurullo, 2017) was central to this process generating key visual outputs. MIRO was utilized for visualizing networks with multiple authors, institutions, key terms, and research clusters, valuable for understanding the interconnections of different research efforts made and identifying influential contributors. Bibliometrix facilitated advanced statistical analysis for gaining quantitative insights (Aria and Cuccurullo, 2017). Tableau created detailed infographics and dynamic data visualizations, enhancing the presentations and communication of the research findings.

Using Biblioshiny software for Bibliometrix analysis, the author gained a detailed understanding about the research landscape on enhancing the Food Supply Chain through Big Data technologies and strategies. Our analysis spans nearly a decade, covering 224 articles (In Bibliography only) published from 2015 to 2024. This analysis provides an in-depth look at key parameters including publication trends, source distribution and focus areas. Figure 6 shows the research summary on 224 articles from 2015 to 2024.

Figure 6

Overview of Bibliometrix Analysis



Note. Aria and Cuccurullo, 2017

Timespan: The defined period over which the study or analysis is conducted, in this research is from 2015 to 2024.

Sources: The dataset comprises 147 sources.

Documents: The dataset used in this study comprises 217 documents.

Annual Growth Rate: The annual growth rate of publications in this field is 23.12%.

Authors: A total of 702 authors contributed to the making of this research paper within the dataset.

Author of Single-Authored Docs: 26 authors who independently conducted the research.

International Co-Authorship: The collaboration of authors from various countries in this research is 29.85%.

Keyword: It indicates that there are a total of 685 keywords that have been utilized in the dataset.

Documents Average Age: It shows that the documents' average age is 3.22, indicating their recentness.

Average Citations per doc: It indicated that the documents have received an average citation of 28.18, reflecting the rate at which the publications are being referred.

Literature Review

Supply Chain Management

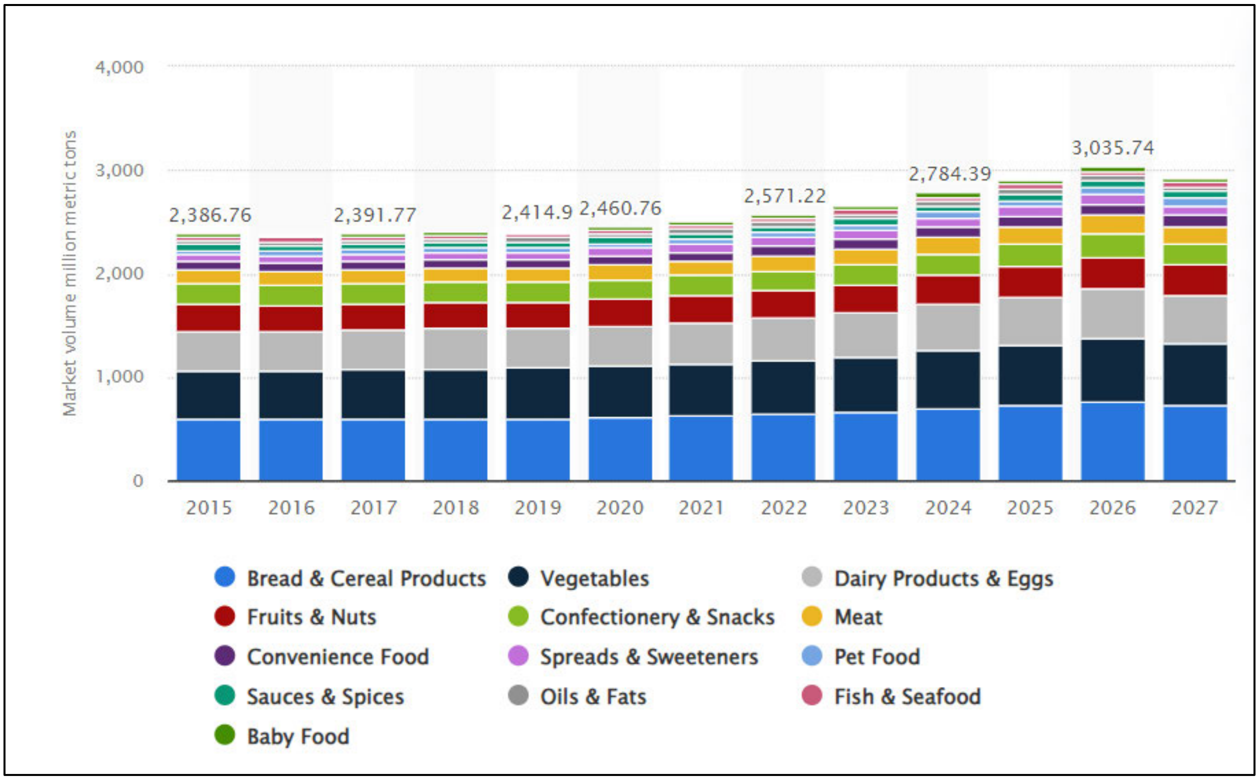
A supply chain passes through the interconnected path that raw materials, components and products take from their origin to their final sale to customers. Manufacturers who process raw materials into processed food, suppliers who buy/sell materials, supply chain managers, retailers who sell goods, manufacturers who manufacture or grow raw materials, transporters and logistic providers who move goods, and consumers who buy and use the products are all part of the chain (McKinsey and Co., 2022).

Global Food Consumption Statistics

As shown in the diagram by Statista, the consumption of food has been continuously growing year to year. In the starting point at year 2015 the consumption is around 2.3 billion metrics whereas it has risen to 2.5 billion by year 2021. Approximately 626 million metric tons, or the greatest category of consumption in 2021, were made up of bread and cereal items (Statista Research Department, 2022). Regarding the global market coverage of consumption, this was closely followed by eggs, dairy products, and vegetables (Figure 7).

Figure 7

Global food consumption from 2015 to 2021



Note. Statista Global

Food waste has increased annually along with the rise in global food consumption. According to McKinsey and Company (2021), food waste and loss have an annual cost of $940 billion and more than 8% of world gashouse emissions. Approximately 250 cubic kilometers, or 3.5 times the US yearly consumption, make up the food waste's blue water footprint. Here, 32% of total loss which occurs during production in developing and emerging countries whereas 38% of total loss occurs in consumption made in developed economies (Food and Agriculture Organization, 2011).

Big Data technologies offer a chance to solve issues related to FSCM. An example of how Big Data deals with industry challenges is presented below (Table 5):

Table 5

An illustration of big data utilization in the food supply chain

Opportunity	**Industry challenge**	**How Big Data Helps**
Optimize farming operation	50% more and better food required in the upcoming 20 years	"Smart Agriculture" by measuring and optimizing food operations
Supply chain Transparency	Lesser amount of oversight in supply chain process High price volatility	Transparency and real-time data collecting in ledgers Organizing along the supply chain procedure
Anticipate waste	Huge amount of food wastage	Collection of data on anticipation of wastage and change in the offerings/process
Deal with infrastructure challenge	Poor infrastructure in market	Advance analytics to identify key bottlenecks Infrastructure network optimization

Note. McKinsey and Company, 2022

As global food consumption continues to rise, so does the complexity of managing the supply chain that must accommodate the increasing demand while minimizing waste and inefficiencies. The data taken into consideration for literature review illustrates the scale of challenges facing the industry, from optimizing farm operations to addressing infrastructure bottlenecks.

Word Cloud

The word cloud produced by the Biblioshiny tool is displayed in Figure 8, with each term's size according to its frequency in the dataset. The term “Big Data” appears in the center with the highest size indicating itself as the most frequently used keyword in the research publications. Following closely “supply chain” also stands prominently in visualization.

Figure 8

Word Cloud

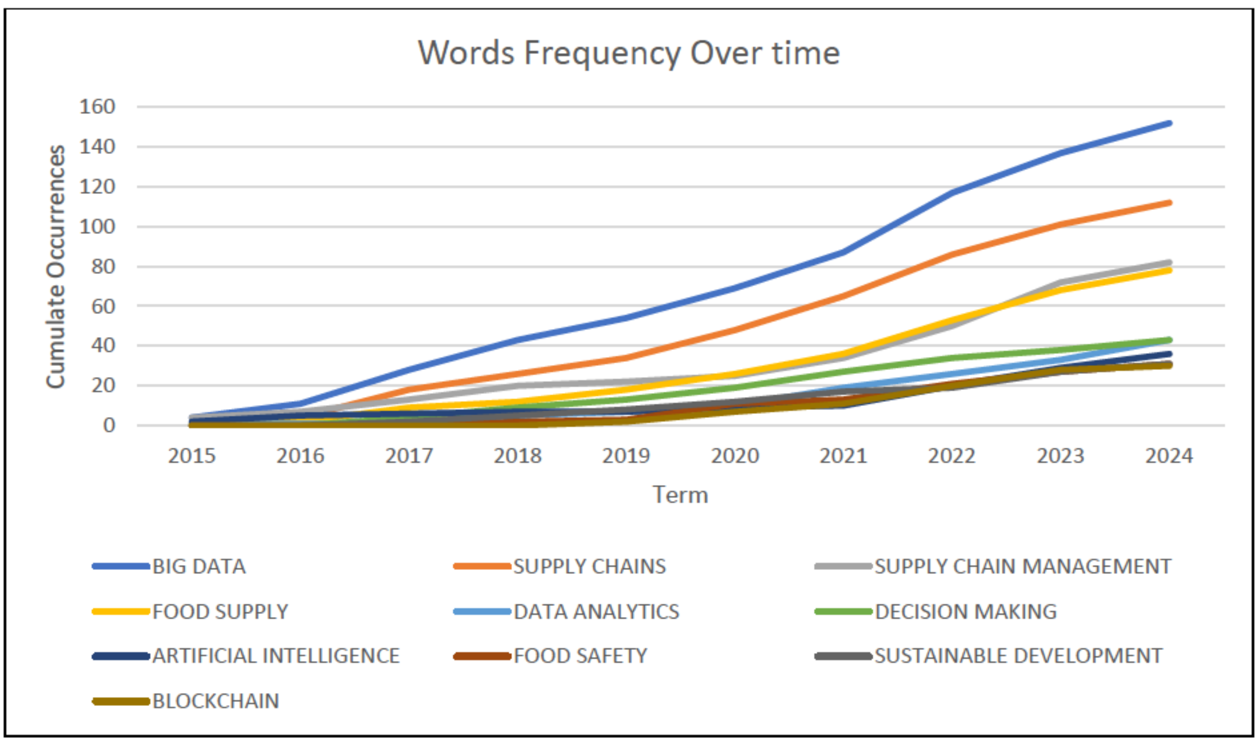
The word cloud created throughout the review illustrates the prevalence of terms with "Big Data" and "Supply Chain" in the literature, highlighting their significance in research and helping readers better comprehend these difficulties. The word prominence in the word cloud reflects the growing academic and practical interest in these areas. To deliver deeper into the trends and evolution of these key over time, a cumulative analysis of keyword occurrences was performed.

Cumulative Occurrence

Figure 9 created using Tableau with data sourced from Bibliography illustrates the cumulative occurrence of keywords from 2015 to 2024. During this period "Big Data" has accumulated the highest occurrence rate totalling 152 and "supply chain" follows closely behind with 112 occurrences.

Figure 9

Cumulative Occurrence Network



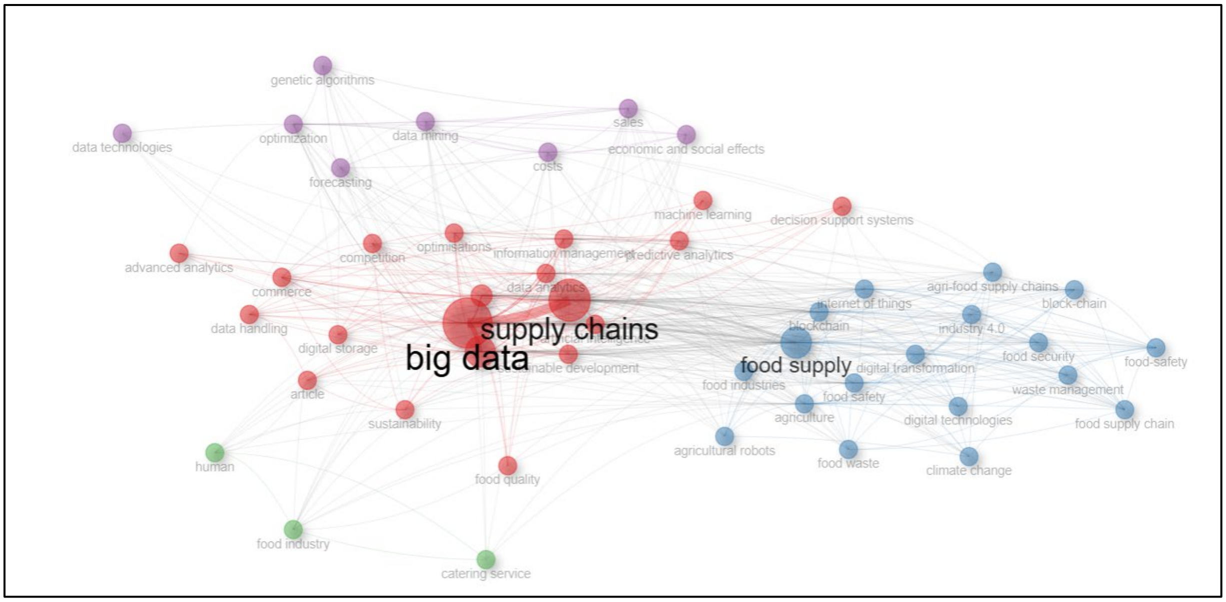
The cumulative occurrence analysis provided valuable insights into the frequency and trends of key topics over time, but understanding the relationships between these concepts requires a deeper exploration. To visualize how “Big data” and “Food Supply Chain” interact with literature, a co-occurrence network was generated.

Co-occurrence network

The co-occurrence network shown in Figure 10 illustrates how "Big Data" and "supply chains" appear frequently and have a strong association in the literature. The visualization underscores their significant interconnection, reflecting the pivotal roles in modern business strategies and operational efficiency across various industries.

Figure 10

Co-occurrence Network



Note. From Biblioshiny

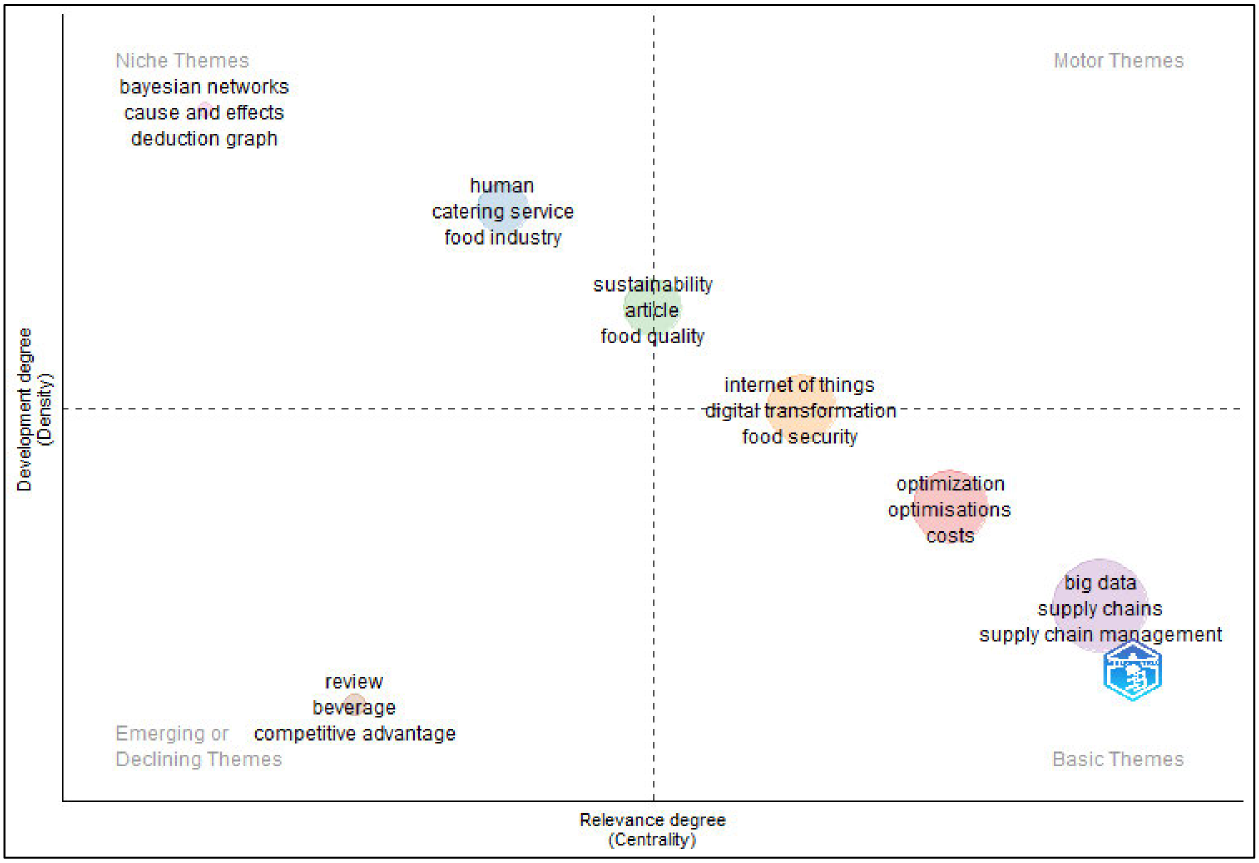
While the co-occurrence network reveals the interconnectedness of key concepts, a deeper understanding of how these themes evolve and interact within the research landscape is provided by the thematic map.

Thematic Map

Figure 11 generated by Biblioshiny, displays a thematic map positioning "Big Data" and "supply chain" and "food security" within the "basic themes" quadrant. This quadrant is defined by high centrality and low density, indicating these topics are pivotal within their field and possess strong connections to other themes, yet they are still emerging and not fully developed.

Figure 11

Thematic map



Note. From Biblioshiny

Findings of Systematic Literature Review

RQ1: What are Big Data applications technologies and strategies currently available for improving supply chain management?

Big Data is the term used to describe the enormous amount of data generated in various forms, frequently more than typical data management systems can process. Numerous sources, including transactional data, sensors, social media, and mobile devices, can produce these datasets (Russom, 2011). Big Data integrates each phase of the business process with technical optimization and analytics in both external and internal environments for multidimensional analysis (Chakraborty et al., 2023).

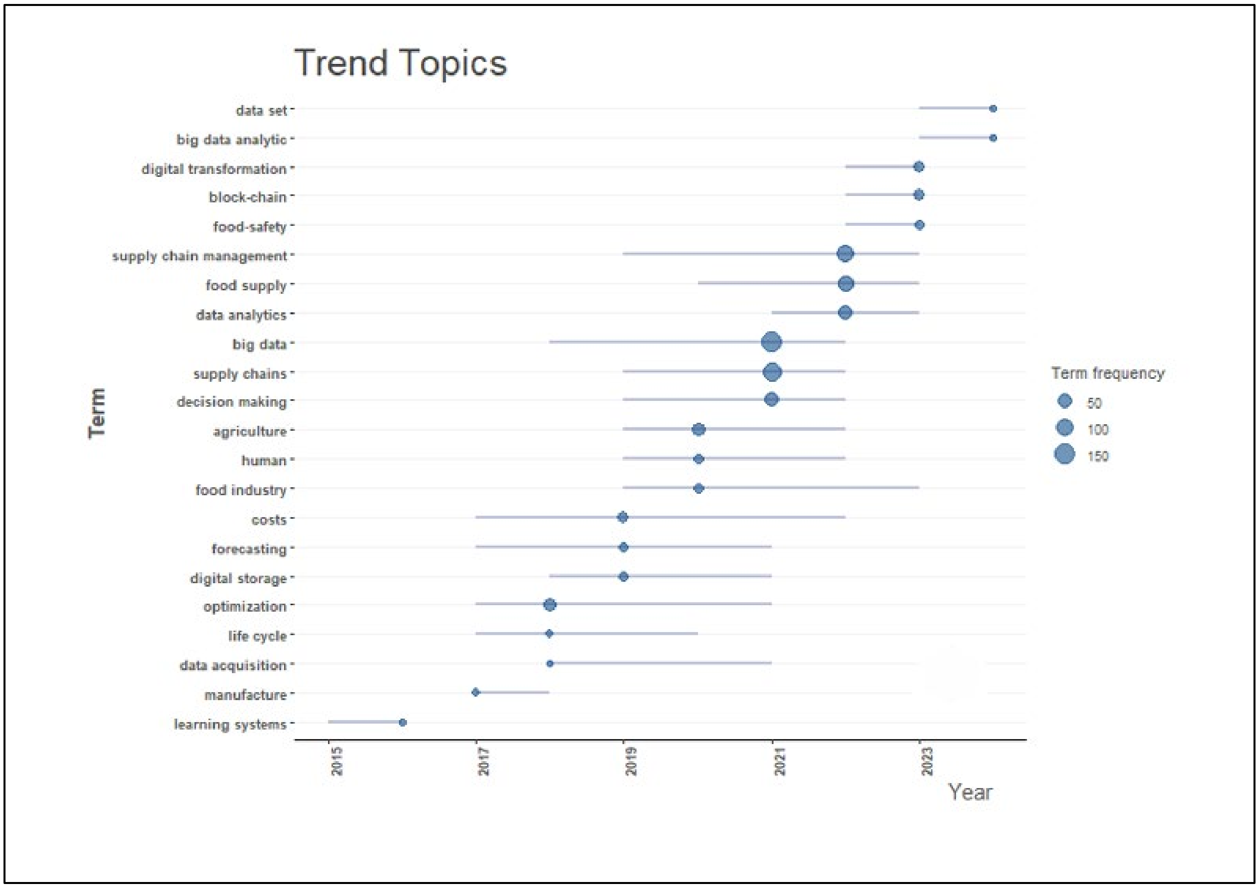
This paper investigates how Big Data technologies can enhance the existing network of supply chains and address specific challenges within the Food Supply Chain. Big Data can be obtained and analyzed using various technologies and strategies including predictive analytics, blockchain, Internet of Things (IoT), machine learning and smart agriculture. This technology improves supply chains by enhancing traceability, efficiency and sustainability. For example,

- Predictive analytics: Helps forecast demand more accurately
- Blockchain: Ensure data integrity and transparency,
- IoT devices: provide real time monitoring,
- Machine learning: Aids in data driven decision making
- Smart agriculture: Optimizes current farming practices.

The review's conclusions show how these technologies tackle issues including lowering food waste, enhancing food quality, and guaranteeing effective food delivery. This exploration helps to understand how these innovations are revolutionizing supply chain management. To understand how these technologies have gained prominence over time, we turn to an analysis of trendy topics in literature. Below figure 12 helps to visually represent this evolution:

Figure 12

Trend Topics Analysis



The trends in Figure 12 depict the evolution of themes based on data frequencies from 2015 to 2024.

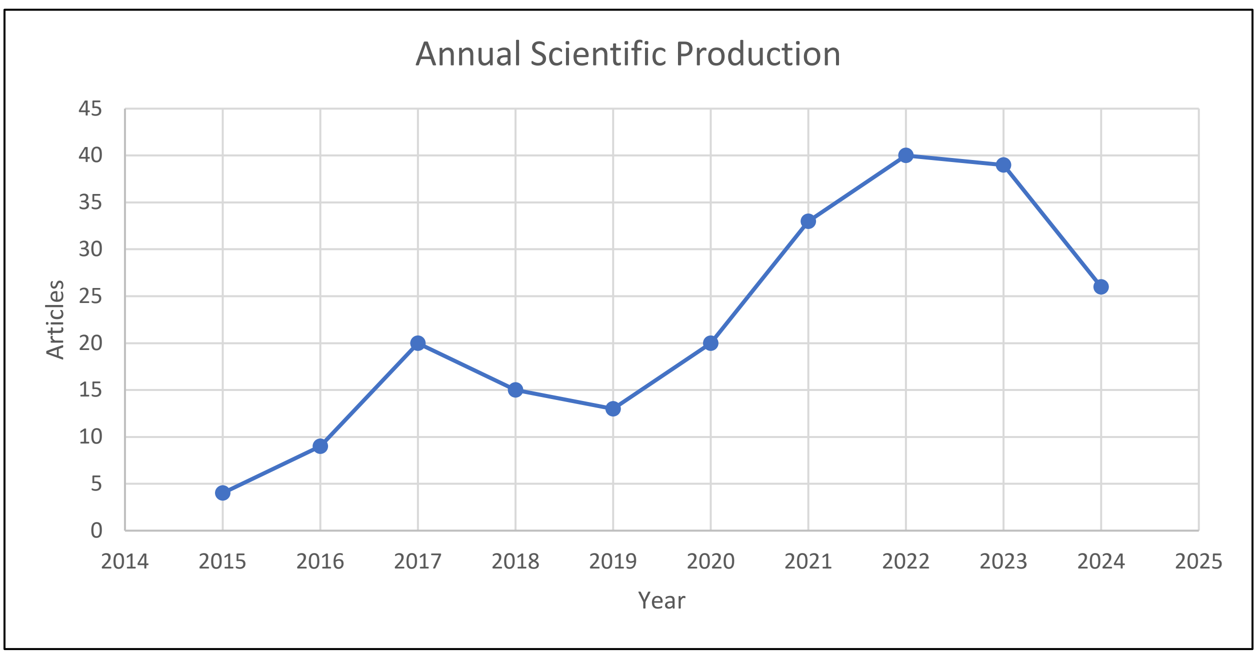
- 2015 to 2018: Foundational topics such as learning systems, manufacturing, and life cycle were prominent, Laying a groundwork for subsequent advancements.
- 2019 to 2020: Optimization, forecasting and digital storage gained focus, indicating an emphasis on efficiency and data management.

- 2021 to 2023: There was a notable pivot towards advanced technologies and strategic decision-making process. key trends during this period included Big Data analytics, supply chain management, digital transformation and blockchain technology reflecting that the industry is moving towards the adoption of operational improvements and innovation (Irfan et al., 2019).
- 2024: There is a continued focus on refining data analytics exploring Big Data applications and improving data sets to leverage greater insights for meaningful data driven decision making.

The trends analysis highlights the evolving focus within the literature on Big Data and its transformative role in supply chain management. To understand the yearly production of articles that has been made in the trending topics lets go through the following (Figure 13):

Figure 13

Annual Writing of Articles Concerning the Application of Big Data in the Food Supply Chain

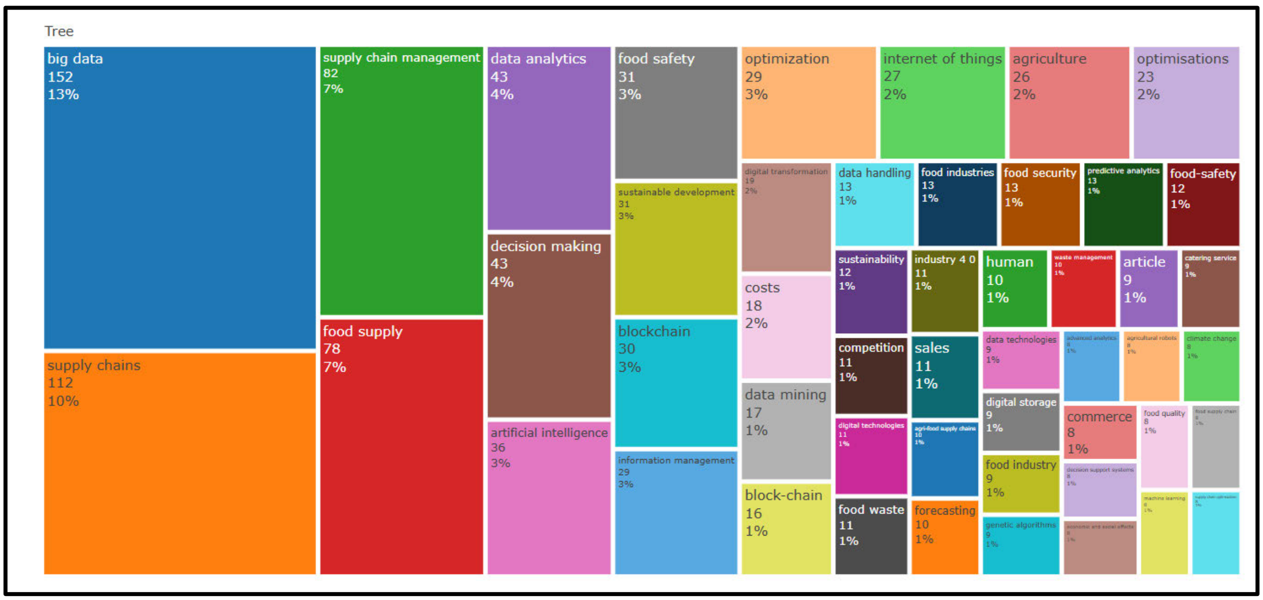


The author examined the release of scientific articles over time and it's evident that the research topic has been more focused in recent years. There has been substantial growth from 2015 to 2024, with a major peak in the year 2022. The surge likely reflects not only technological advancements but also an increased urgency to address practical challenges in the food supply chain like resilience, sustainability and efficiency – especially in light of the pressure of global disruptions (Tchonkouang, et al., 2024). The findings above are a valuable insight for researchers, institutions and funding agencies to identify significant work.

To further understand the research landscape, the tree map in Figure 14 provides a visual representation of the frequency of keywords used in studies. The progression of articles can be depicted in the tree map as follows:

Figure 14

Tree Map



Note. From Biblioshiny

The frequency of terms used in studies on big data and the food business is depicted in the above diagram. The most repetitive keyword used is ‘Big Data’ (150 occurrences) indicating significant research interest and market desire to upgrade the current supply chain process with Big Data applicability. Other keywords are “supply chain” (112 occurrences), food supply (78 occurrences), data analytics (43 occurrences), and Artificial Intelligence (AI) (36 occurrences). The tree map is used for visualization (Jadega and Shah, 2015), and depicts the frequency of keywords used in the sample related to enhancing the Food Supply Chain Management through Big Data application and strategies. The size of each segment in the tree map is correlated to the frequency of keyword occurrences, providing that visual input to understand the overall literature review. This analysis helps to perform industry analysis, and technical challenges, and set future expectations for upgrading the supply chain process.

Big Data holds significant potential for enhancing efficiency and effectiveness in Food Supply Chain Management (Ji et al., 2017). Given the complexity of the supply chain involving multiple stakeholders, Big Data can streamline actionable insights at each stage of the process. Data collected at various phases can be analysed to predict demand and supply fluctuations (Russom, 2011). Big Data is utilized across the supply chain for demand forecasting, inventory management, procurement process, production and logistics (Wang et al., 2016). This paper explores a variety of Big Data applications technologies and strategies, currently available for improving the supply chain management process.

A. Internet of Things (IoT)

One useful method for gathering data from several sources is the integration of IoT systems in the food supply chain (Protopop et al., 2016). IoT sensors gather location, temperature, and humidity data in real time, which is crucial information about how food products travel through the supply chain (Lezoche et al., 2020)

IoT has the potential to provide traceability, visibility, and controllability across the food supply chain, from farm to plate, according to a survey done in 2015 by Li et al (Li et al, 2015). IoT platforms are essential for improving food supply chain traceability (Shih and Wang, 2016). IoT and blockchain technology can be integrated into the food supply chain to provide consumers with more transparent and productive food quality monitoring, as well as trustworthy real-time information for clients and stakeholders. With IoT sensors, evidence can be generated to verify if pathogenic and parasite contamination is being transferred through frozen food packages, which typically highlights the importance of traceability for maintaining the food quality and safety (Mondal et al., 2019).

IoT technologies are effective in managing various aspects of food, such as seeding, and temperature control and enhancing coordination during natural outbreaks, mitigating issues caused by bad food (Xiao, 2014). A smart sensor that is integrated with an RFID (Radio frequency identification detector) tag was created by Lorie et al. (Lorie et al., 2017) in order to facilitate real-time food supply chain monitoring. IoT integration combined with a blockchain-based system can provide a dependable and traceable food supply chain (Verdouw et al., 2016). The main areas found employing IoT in the food business are outlined in Table 6.

Table 6

IoT application in the food sector

Applications of IoT in the Food Supply Chain	Objective	Source
System for managing cold chains	Reduce the expense of shipping and storage	"Kuo and Chen, 2010"
Using virtualization to make decisions	Manage, organize, and streamline the fish distribution business process.	"Verdouw et al., 2016"
Food – IoT	Traceability, visibility and controllability	"Li et al., 2015"
Cold chain system using IoT architecture	Food preparation and effective conveyance	"Prim et al., 2021"
Integrating intelligent sensors for monitoring in real time	Temperature regulation for the quality and safety of food	"Feng et al., 2022"

Most of the instances highlight how crucial traceability is to the supply chain process's overall food safety and quality. Many companies like Walmart, IBM Food Trust, Te-Food, Danone have already adopted IoT for many different purposes like traceability, quality management, real time monitoring and obtained successful increase in efficiency and output. Consumers are putting more and more pressure on businesses to increase product visibility and traceability because they want to know where the goods they buy are coming from. In general, the food supply chain has undergone a paradigm change toward the use of technology, particularly the Internet of Things and intelligent sensors.

B. Blockchain in Food Supply Chain

Blockchain technology offers a safe, transparent, and effective method for recording and authenticating transactions, making it a crucial tool for improving food supply chain management (Deloitte, 2017). Each transaction or block has a unique signature and is linked to the previous one for encryption and hashing purposes. The transparent ledger ensures that the data cannot be deleted or edited and provides real time reconciliation amongst vendors so that they can rely on supply chain information. Data is protected thanks to advanced encryption methods, and food packaging QR (Quick Response) code associations will preserve all the evidence that has been acquired along the supply chain. Customers can obtain complete traceability data, including the product's origin, by scanning codes (Deloitte, 2017).

Case studies

- **Agridigital:** Data from several lifecycle stages, including growing grain, production, and transportation, are gathered by an Australian agriculture commodities management platform and combined for claims. According to Rogerson and Parry (Rogerson and Parry, 2020), every claim regarding the product's organic status is hashed and documented on a private quorum blockchain layer. Weighbridges with RFID capabilities may identify, and measure tagged cars, recording their location, weight, and time on the blockchain. Next, a web program is utilized for product packaging and to ascertain whether a product is truly or falsely organic (Rogerson and Parry, 2020).
- **Techrock:** It provides parents with product assurance concerning the source of baby formula. They make use of smart packaging, in which an RFID tag readable by a smartphone is attached to a wire that serves as an antenna to determine the legitimacy of the goods being scanned. This strategy tackles worries regarding melamine contamination

of powdered milk products, a poison that killed 300,000 infants in 2008 ((Rogerson and Parry, 2020).

In global logistics, blockchain are based on smart contracts and distributed ledger technology maintains container information such as humidity and temperature. Real time data sharing shall ensure the quality and safety of transported goods. Blockchain visibility helps banks to provide loans to farmers with reduced risk and buyers can verify the authenticity of seller's assertions regarding the quality of food through smart contracts (Abideen, et.al. 2021). Thus, blockchain can effectively optimize the current Food Supply Chain Management process.

C. Artificial Intelligence

Artificial Intelligence aids a significant role in decentralizing and innovating FSCM. AI technologies contribute significantly to knowledge models, decision making process and service creation in Food Supply Chain. These techniques are essential for developing prediction model, performance evaluations and pattern classifications (Abideen, et.al. 2021). These capabilities help address challenges in the supply chain process, supporting advancements from farming techniques to supply channels.

Case Studies

- **Yield Technology Solution:** This organization places sensor nodes in different corner of agricultural fields, communicating data to Microsoft Azure cloud for storage and processing. AI collects microclimate data and use it to predict and make decisions such as when to grow, harvest, water and safeguard crops (Misra et al., 2020).
- **Japan Bosch Corporation:** It has introduced Plantect, a greenhouse focussed technology that collects environmental condition from all greenhouses through sensors. This data is

compiled and analysed using AI and cloud computing to forecast disease outbreaks and provide management recommendations for pest control (Misra et al., 2020).

- **Project IoF (Internet of Food and Farm, 2020):** This project, which was funded by the European Union under Horizon 2020 and directed by Wageningen University, focused on the "Farm of the Future" and attempted to adapt and translate "internet of things" technologies to the conditions of farms.

The United Nations estimates that $750 billion, or one-third of the world's food supply, is wasted year (Misra et al., 2020). The Food Chain of Supply confronts difficulties in controlling perishables, varying supply and demand, and achieving strict standards for food safety and sustainability (Internet of Food and Farm, 2020). AI can improve technical feasibility, intelligence, data quality, and accessibility, leading to long term revenue gains and industry performance improvements. AI enhances forecasts and mitigate disruptions, protecting supply chain from potential risks. Another concern is ensuring food quality and traceability (such as with blockchain) where AI can enhance traceability and shelf life supporting blockchain platforms in developing robust system (Lezoche, et.al, 2020).

D. Smart Agriculture

Smart agriculture also referred to as digital agriculture (Lian et al., 2002) leverages cutting-edge technology to achieve critical farming objectives (Eastwood et al., 2019a) such as water conservation, soil preservation, reducing carbon emissions and enhancing productivity by maximizing resource efficiency (Lezoche, et.al, 2020). This approach in smart agriculture aims to modernize current practices and promote sustainable farming.

Supporting cooperation between farmers, technology suppliers, service providers, governments, and other stakeholders like investors and merchants is the aim of smart agriculture

(Senturk et al., 2023). By working together, all parties involved in the food supply chain are able to recognize one another, learn about the Information and Communication Technology (ICT) services that are available, and communicate their expectations and concerns. This preserves sustainability and results in an agricultural supply chain that is optimized (Wolfret, 2017).

Smart sensors and IoT devices collect data on agricultural products from the field to the store. The information generated from production, warehousing and retail availability is collectively referred to as Big Data (Carolan, 2018). Smart agriculture automates data collection, eliminating the necessity for entering information manually at every stage and minimizing potential human error (Manzini, 2013). Farmers are at a distance from technology, as they still depend on old agriculture and food delivery systems. Farmer's problems can be solved using modern technology such as big data analytics, blockchain technology, artificial intelligence, IoT, and can revolutionize agriculture through mass data collection from sensors (Li and Wang, 2017). An example of smart agriculture is, predictive analytics can forecast crop yields, enabling better planning and reducing waste (Kumar and Dwivedi, 2023).

Massive data analysis enables farmers to make decisions based on data backed by comprehensive historical data, current conditions and future forecasts. The IoT sensors placed on the soil can extract real time information like moisture level, nutrient availability, and weather conditions. Sustainable agricultural methods can be achieved by optimizing the use of pesticides, fertilizers, and water through the use of big data.

In the food supply chain, traceability and transparency are improved by integrating data from manufacturing to retail. By adding an additional layer of security to this data, blockchain technology can guarantee food safety and minimize losses from spoiling or inefficiencies. Big Data integration with smart agriculture facilitates better decision-making, maximizes resource use, and boosts supply chain effectiveness, opening the door to a more productive and sustainable agricultural industry.

RQ2: How can Big Data technologies and strategies be applied to different stages of the supply chain?

A. Using Big Data in the Agriculture Supply Chain

The implementation of tracking and tracing systems, sustainability analysis, and enhanced decision-making are the main goals of big data utilization in the agriculture supply chain. Farmers can make an informed decisions that promote efficient resource use and improve sustainability by evaluating data from multiple sources, including soil sensors, weather forecasts, and crop health monitoring. While big data technologies can assist in managing the data, predictive and prescriptive analysis support in making an informed decision making (Wolfret et al., 2017). The major portion of water gets consumed in agriculture, but with growing uncertainty of rainfall, climate change and global alarm, risk is high. It can assist with choosing the appropriate use of water and making predictions based on data gathered from sensors and intelligent irrigation systems. Few studies have been conducted on the application of artificial neural network algorithms for rainfall prediction (Ashaary et al., 2015).

Author observed (Coble et al., 2018) that artificial intelligence can aid in the early detection of Pest attacks. He also stated how artificial intelligence can predict corn and soybean fields with accuracy by considering multiple soil properties as input. Support vector machines were employed in another study by Rumpf et al. (Rumpf et al, 2010) to create proactive crop disease identification methods.

Smart agriculture, which aims to achieve efficient use of natural resources and a systematic agriculture process, is made feasible by effective data gathering, analysis, and early prediction through Big Data applications. Companies like John Deere are leading this charge, using data analytics to improve crop yields up by 15% and reduce input costs by 10%, and have ensured more sustainable food supply chain.

B. Using Big Data to Increase the Efficiency of the Food Supply Chain

In the Food Supply Chain, Big Data can significantly enhance efficiency by integrating supply chain operations with demand forecasts and coordinated distribution processes. Through Big Data analytics, stakeholders can predict demand more accurately, manage inventory efficiently and optimize logistics to reduce costs and improve overall service (Wamba et. al., 2017). Maintaining equilibrium in logistics and technology use are critical components of success for manufacturers and retailers. If the correct product is delivered to the right clients at the right time while retaining cost efficiency, efficiency can be reached in this process (Lozano, 2017). Walmart utilized Big Data Analytics to understand consumer purchasing patterns, allowing them to adjust inventory in real time and it has boost their efficiency by 10-15%.

A major portion of food waste, approximately 20% of the world's food supply, can be attributed to logistical issues. When implemented in the food supply chain, IoT solutions can lower the number by 10% to 15% (Ahmadzadeh, 2023). An integrated Internet of Things (IoT)-based autonomous storage identification system can monitor the products being sent, including transportation and registration details, making the entire process transparent and lowering the risk of contamination (Belaud, 2019). The instrument facilitates temperature monitoring, anti-theft features, and tray traceability. Nestle have harnessed Big Data to optimize logistics achieving up to a 30% reduction in costs, providing more transparency and efficiency.

The use of big data can create an environment where close monitoring for product type quantity and status is possible (Saroha et al., 2018). Big Data application enable operations to make more accurate decisions, lead to continuous product improvement and create simpler processes.

Big Data analytics ensures a seamless flow of goods from producers to consumers, minimizing delays and wastage.

C. Using Big Data to the Food Supply Chain to manage food quality

Throughout the whole food supply chain, big data has played ma major role to control the food quality and food safety. Social media analytics and sensory data analytics can be used to identify current trends and put necessary strategies into action to ensure food items fulfill standards and safety criteria. Analysis and monitoring of product quality in every phase of the supply chain are made easier by real-time data gathered at several stages (Verdouw et al., 2020).

When big data is available, it is possible to connect IoT networks in order to gather and analyze data from farmers all the way to the end of the supply chain, merchants, and consumers. The precision agriculture method facilitates the use of robotics, sensors, big data analytics, and the Global Navigation Satellite System (GPS) in agriculture production systems. This allows for the generation and processing of unique information obtained along the supply chain. As a result, the information gathered can be used to improve the process of making decisions regarding food safety and quality, decrease environmental effects, forecast and prepare for an increase in production crops (Donaghy et al., 2021). Companies like Danone employs IoT devices to monitor dairy products in transit, cutting spoilage by 15%, Unilever has seen 30% improvement int traceability and efficiency and Dole Food Company has resulted in 25% reduction in quality related issues after adoption of IoT, Blockchain and AI in their business (Tejero et al., 2019).

The Food Supply Chain still involves a lot of manual operations, but this can be altered by using IoT-driven food processing machinery (Tejero et al., 2019). Water dispensing, food cleansing and disinfection, and pest monitoring are all possible with IoT, and these applications will be crucial to the control of food quality. Automation of the supply chain's repetitive processes can increase efficiency, and digital content can help with understanding customer expectations (Hasnan and Yusoff, 2018). Similarly, permanent, verifiable record keeping enabled by blockchain technology has the potential to transform the food system by promoting efficiency, transparency, and cooperation all the way up the supply chain (Antonucci et al., 2019).

D. Utilizing Big Data to reduce food losses throughout the Food Supply Chain

Food loss has a significant impact on global sustainability and is a notable issue in the food supply chain. According to research on food waste management, between 46% and 65% of the food waste produced by the food supply chain is generated at the consumer level; the remainder is produced at various other (Production, distribution) stages of the chain (Annosi et al., 2021). The primary cause of food waste is the overproduction of food compared to market demands. The most desirable strategy that researchers have suggested in terms of effectiveness is to avoid surplus generation of food supply from production to consumption (Annosi et al., 2021).

Big Data solutions, such as market mediation, can help achieve this by storing, transmitting, and processing data collected from a variety of sources. These data then enable connectivity between businesses providing high-quality information sharing, including prompt food and ingredient transfers along the supply chain and the safety of food items by ensuring sufficient product shelf life (Annosi et al., 2021). Digital technology shall support in supplying exact number of products based on real time insights so that the retailer can easily meet consumer’s need by preventing over production.

Big Data may be used to create intelligent packaging systems so that goods remain perishable, maintaining the quality of goods and protecting them from spoilage or waste. Making the appropriate judgments at the right time is facilitated by real-time information gleaned from the supply chain regarding the state of food goods (Galanakis, 2020).

Businesses in the food sector have employed digital solutions for performance optimization and traceability, such as Power Business intelligence (Power BI) performance tracking systems. To identify performance gaps and stop food waste, gathering data on manufacturing, logistics, and the entire supply chain is very helpful. Large companies that may monitor and trace and evolve together with Business to Business (B2B) connections with vendors and consumers utilize track and trace systems extensively and intensely (Annosi et al., 2021). Managers are now able to identify problems early on and stop food waste since blockchain technology has made the entire process safe and transparent. Reducing food waste/loss and lowering carbon emissions are the two primary objectives that big data can accomplish (Govindan et al., 2018). By integrating digital systems and technology, food waste can be effectively prevented both within an organization and throughout the entire food supply chain.

E. Utilizing Big Data Applications in Urban Food Supply Chain

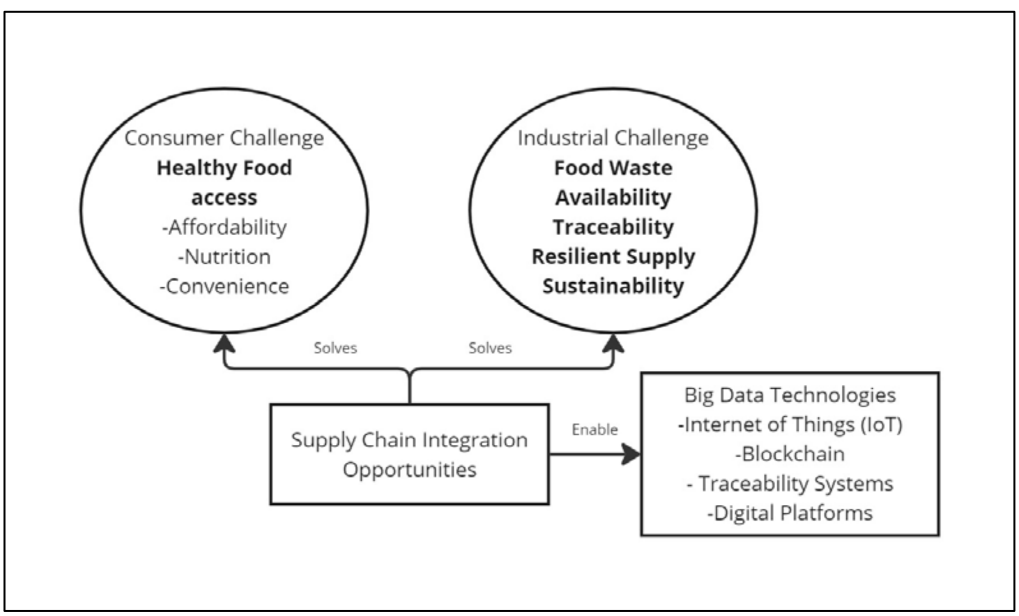
Urbanization poses significant obstacles to the Food Supply Chain, requiring more coordination and timely replenishment to maintain demand and supply balance. Big Data technology supports logistics efficiency, tackles food security and ensures food safety. By optimizing transportation routes, managing inventory, and ensuring timely delivery of food products, Big Data addresses the unique challenges of feeding growing urban populations (Choi et. al., 2019).

In metropolitan areas, a number of businesses are becoming digital enterprises by combining their operations with digital platforms. Large companies like Amazon are using data to use digital platforms and Big Data to increase their future commercial potential. Digital technology is also being used more and more by the food supply chain to address issues in the urban food supply chain. The architecture provided below assists in tying issues with the urban food supply chain to potential digital remedies (Mantravadi, 2023). Businesses and professionals, for instance, can investigate how big data can improve product authenticity and traceability (i.e., organic food production).

By cutting lead times and reducing waste, these technologies can also assist lower food losses. Producer costs should decrease because of these initiatives, and consumers should benefit from higher-quality and more reasonably priced products (Figure 15). For management of urban Food Supply Chain, it is important to create synergy among multiple producers and retailers/consumers by connecting them and ensuring there is efficient communication between them (Mantravadi, 2023).

Figure 15

Urban areas framework for Supply Chain Integration



Note. Soujanya et al., 2023

Stakeholder cooperation in a food supply chain is a key component for achieving results for urban food systems, according to our review of the literature. Although it takes time and work to cultivate a digital mindset, successful urban food systems will eventually result from it.

Limitations

- The study primarily focuses on the available Big Data and their applications within Food Supply Chain Management, however newer developments in areas such as neural networks and cloud computing were not included (Kshetri, 2014).
- The research shows a region-specific analysis, limiting the capability to fully capture the global landscape of Big Data applications in Food Supply Chain Management. The application of this technology shall vary widely between a developing country (Marsden et al., 2000) and developed countries, leading to potential bias in understanding the universal applicability.
- While the paper covers a wide range of technologies including IoT, AI and smart agriculture, the number of case studies for blockchain and machine learning is limited. This restricts the ability to draw suitable conclusions about their effectiveness and scalability in diverse contexts.
- The paper shares about the potentially high expenses of integrating big data technology with small and medium-sized food industry businesses. However, it does not provide detailed cost benefit analyses (Knechtges, 2011, Brinch et al., 2018) which are crucial for understanding the practical implications of these technologies.

Addressing limitations

To overcome these limitations identified in the study, several steps can be taken to enhance the comprehensiveness and applicability of future research on Big Data technologies in FSCM.

- Future research should incorporate newer developments such as neural networks, and cloud computing. With such incorporation, the research outcome can provide a holistic view of new advanced computing solutions that impact on outcome.
- The geographical limitation can be addressed by expanding the current research region to a more diverse range of countries. It helps in having a more accurate global landscape of big data applications in FSCM.
- The in-depth research on new topics like machine learning and blockchain can provide better insights into the effectiveness and scalability.
- Future studies should pay close attention to small and medium-sized businesses and their thorough cost-benefit analyses to determine their financial standing and return on investment when implementing big data solutions.

Conclusions

The purpose of this literature evaluation is to systematically organize previous studies on Big Data Technology in Food Supply Chain Management and assess their effectiveness in addressing industrial challenges. This review emphasizes the importance of selecting the right methods and tools to tackle critical issues within the food supply chain sector.

- The results showed that Big Data efficiently addresses issues in five key areas: the urban food supply chain, agriculture supply chain, food quality management, and agriculture supply chain improvement.
- The capacity of organizations to leverage Big Data applications, particularly in upstream operations, significantly impacts their success in these areas.
- The study highlights gaps in the current research, including a limited number of studies on blockchain, artificial intelligence, and machine learning within the scope of food supply chain management (FSCM).
- The existing literature is regional-specific, limiting the global applicability of the findings.
- While addressing food wastage through Big Data is crucial, smaller organizations face overcoming high costs and technological adoption barriers that must be overcome.

Future Research Directions

The study concludes that future research should focus on leveraging technology to create more transparent systems that enhance food safety, quality and wastage control.

- Expanding studies to include more diverse geographical regions can provide a comprehensive global perspective, addressing the current limitations of region-specific analysis.
- Developing cost effective Big Data solutions for small and medium level enterprises will be crucial for widespread adoption and effective implementation.
- Examining the Food Supply Chain's technology integration and interoperability will aid in resolving present technical issues and enhancing system performance.
- Conducting detailed economic assessments to understand the financial feasibility and cost benefit aspects of implementing Big Data solutions.
- Adding more recent advancements and cutting-edge technology, like cloud computing and neural networks, to improve future evaluations' thoroughness.

Future studies can improve our knowledge of Big Data applications in FSCM by tackling these topics, which will result in a more robust and effective food supply chain. This will provide a clearer big picture and guidance for the food industry to become more sustainable and efficient.

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