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Original Article

RFID Technology in Storage Management: A Bibliometric Study on Efficiency and Cost Reduction in the Retail Sector

Juan Carlos Quiroz-Flores[1], Martín Fidel Collao-Diaz[2], D. Sobya[3], S. Nallusamy[4]

[1]*Faculty of Engineering, Industrial Engineering Career, Peruvian University of Applied Sciences, Lima, Peru.*
[2]*Faculty of Engineering, Universidad Continental, Lima, Perú.*
[3]*Department of Electronics and Communication Engineering, Raja Rajeswari College of Engineering, Bengaluru, India.*
[4]*Department of Adult, Continuing Education, and Extension, Jadavpur University, Kolkata, India.*

[1]*Corresponding Author : pciijqui@upc.edu.pe*

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Abstract - *All retail companies have stock issues regardless of size or age. Radio-Frequency Identification (RFID) technology might be used to keep tabs on tagged goods in the warehouse and provide a more reliable stock count. This study focuses on using RFID technology for inventory management and supply chain processes in the retail sector. Bibliographic reviews of articles published in Scopus between 2017 and 2021 with keywords were used as the methodology. 188 english-language articles from peer-reviewed academic journals were chosen for analysis and visualization using VOS viewer and bibliometrix software. The findings suggest that incorporating RFID into inventory management and supply chain operations can boost efficiency and cut costs in the retail sector. Countries and periodicals with the highest output of RFID-related articles in the niche market were determined, along with the most prolific authors and critical terms in this literature. Furthermore, a positive correlation was discovered between strategic management accounting and the supply chain, and the significance of cooperation and coordination within the supply chain was highlighted. The study's limitations include its reliance on Scopus as its sole data source. However, managers and decision-makers in the small business sector may find the study's findings helpful when contemplating RFID implementation for inventory management and supply chain tracking.*

Keywords - *Inventory, Radio Frequency Identification, Retail, Supply chain, Storage management, Bibliometric.*

1. Introduction

RFID may improve Supply Chain Management (SCM) by collecting and sharing data [1]. RFID may increase Supply Chain (SC) traceability and visibility, and this information is primarily utilized to monitor actual inventories without seeing the goods. German Metro introduced RFID to its suppliers and decreased product losses in transit by 11-14 percent. It increased shop availability by 14% and lowered delivery costs by 11% [2].

Since RFID technology does not yet give real-time data, surplus stock is used to smooth out demand variations [3]. RFID could aid in correcting Inventory Record Inaccuracy (IRI), the disparity between a company's management system and inventory [4]. Stockouts and unnecessary replenishing by IRI harm retail [5]. According to [6], IRI may incur expenses over 1% of sales and 3% of the total revenue. The authors [6, 7] discovered errors in 51% of retail company data, and 30–80% of retail store data found IRI errors in 65 percent of 369,567 inventory records from 37 retailers. RFID can improve SCM, including traceability, perception, process efficiency and speed, information accuracy, inventory loss reduction, and real-time information processing.

Based on the presented issue, the following research queries guide this study:

RQ1. Does current research explore the effect of RFID on reducing IRI?
RQ2. Is it possible to have an IRI of 0 using RFID?
RQ3. Does current research explore the effect of RFID on increasing order variability with stable demand?
RQ4. What were the limitations, consequences, or disadvantages when implementing RFID?
RQ5. How much study has been done on RFID's potential uses in big, medium, and small businesses?

RF scanning is used to read RFID tags [8]. There is no need for direct eye contact or even proximity between the tag

and the reader [9]. Tags, readers, and computers programmed to do specific tasks are the "three essential components of RFID systems". A microchip in the tag holds the encoded data, a Radio Frequency (RF) antenna in the reader picks up the signal, users may contribute data, and a computer keeps track of everything. Data is filtered and managed through middleware, sometimes known as Enterprise Resource Planning (ERP) software [9].

The authors state: "There are two basic kinds of RFID tags: active and passive." Active tags are self-powered [10, 12]. It also discusses semi-passive tags with tiny batteries. However, it has other classifications. Tags may be read-only (programmed at the factory), one-write and multiple-read (enable one reprogramming), or read/write LF, HF, and UHF [10].

Communication and tag-powering couplings determine the frequency range, showing that LF tags are better in humid situations, HF and UHF tags are better in dry environments, and they have a more comprehensive coverage and reading ratio but use more power [11, 12]. Most research focuses on higher-precision sensors for reduced power consumption. A passive UHF RFID tag with a high-precision temperature sensor would save electricity [13].

Smaller, cheaper, and more effective RFID components [14]. Thus, supply chain RFID applications have increased [15]. RFID is used for access control, process management, and tool tracking. Production, government, retail, hospitality, and travel employ RFID applications [16].

RFID benefits the retail, healthcare, textile, automotive, and luxury goods sectors [17]. According to [18], Procter and Gamble and Wal-Mart employed RFID technology to reduce inventory by 70%, service by 99%, and administrative expenditures by reorganizing their SCs.

RFID produces more than $1.3 billion in supply chain income, yet misplaced or lost product cuts profits by 20%. Unreliable inventory management hinders supply chain efficiency and business performance [16]. Retail employees were interviewed about their experience using RFID.

The best feature they could point out was the inventory count, which is difficult to follow and unfavourable for managers who prefer that employees keep attending to customers, and the functionality of locating an object out of place and correcting the inventory on the shelves [19].

RFID reduces SC costs. Tag control points limit human error, supporting this contribution. RFID technology enables organizations to communicate detailed information about their inventory [20, 21]. Instantaneous communication makes decision-making easier. Waste reduction and time and money savings justify RFID use. RFID improved shipping and total time by up to 80% in Central Distribution Centres (CDC) and Local Distribution Centres (LDC) [16].

The remainder of the bibliometric study is divided as follows: theoretical background, methodology, findings and discussion, and research conclusions.

2. Theoretical Foundation

RF waves identify items using RFID. RFID system essentials are [22]:

1. A transmitter-receiver RFID reader.
2. A transponder (tag) that receives, amplifies, and retransmits.

Companies are known to do their hardest to figure out how many units are in their warehouse, and RFID technology allows them to track each unit conveniently and efficiently once it leaves the plant. This technology allows all this data to be securely transmitted across short or long distances. Each product in the warehouse can be tracked and traced using long-range apps [23].

RFID adoption is driven by the automation of current registration and material flow activities, visibility and stock reduction, and short-range RFID tag reading and editing. However, researchers have raised several concerns about this new technology, including a lack of standardization (RFID management software), management difficulties due to the volume of data generated each day, information quickly exchanged between various supply chain business partners (lack of security), and the system's high implementation cost as severe and critical aspects in the implementation of RFID.

The literature lacks case examples for this new technique [24]. Most medium and large organizations employ Just in Time (JIT). JIT delivery implies components are utilized immediately. These circumstances usually cause out-of-stock. RFID might solve this RFID's drawbacks with, i) Data access and storage: the tracking of each object must be stored and consulted quickly, but due to the large amount of data generated each day, it would be hard to keep track of, ii) Accuracy: While the need for real-time information grows with operations, and their underlying information systems, the automatic identifying data of items and the specifications entered into those systems will always strive for absolute precision. iii) Interference: As wireless devices like phones, PDAs, radios, and others grow increasingly widespread, large-scale automated identification systems may experience electromagnetic interference [25].

In RFID-enabled supply chains and warehouses, cargo theft and personnel mistakes cause missing tags. Multi-reader Missing Tag Detection (MMTD) has been developed [26]. A distributed network of readers examines an integrated

RFID system's monitoring region for missing tags. Reader-to-Reader Collision (R2Rc) happens when two readers have a redundant communication area. MMTD pinpoints missing tags using absence set intersections. Readers may get missing tags for each category [26]. Azevedo and Carvalho also stated that RFID deployment faces privacy issues, technological difficulties, and incompatibility with current information systems [27]. Eurostat found that just 3% of EU companies used RFID in 2010. Personal identification and access control (56%), SC tracking and inventory control (29%), highway tolls (25%), theft control (24%), production control (21%), and asset management (15%) were the most prevalent applications of this technology [28].

RFID replaces barcodes in retail, logistics, and healthcare. RFID users include Wal-Mart, the US Department of Defence, Procter & Gamble, and Metro Group [29]. Cycle counting solves the IRI issue. Staff regularly count the retailer's physical inventory. Cycle counting loses time and money but helps firms discover IRI circumstances [30]. With RFID, many retailers choose handheld RFID readers for cycle counting. RFID can have a five- to eight-fold cycle counting speed [28]. RFID aids the SC because of its unique product identification, ease of connection, and availability of real-time information [31]. RFID improves SCM; however, data storage and transfer are insecure [32, 33]. Blockchain technology may also affect the SC's future [34]. Each Blockchain product's platform stores product data from transactional features. These procedures may show the product's quality, owners, and release date to improve recyclability and carbon emissions [35]. This system tracks all of the company's products. Faster and cheaper technologies can enhance reverse logistics. Blockchain technology may use real-time product data to examine the product life cycle [36, 37].

The blockchain is used in marine transport, agriculture, and pharmaceuticals [38, 39]. Tracking RFID and blockchain technologies may be used in transportation and logistics organizations with intelligent contracts like RCS to pay suppliers for high-quality and quantity warehouse deliveries [40].

To digitize, the new industry 4.0 standards and sustainability strategies must achieve high performance and sustainability [41]. Blockchain technology requires substantial hardware, software, and resources [42]. Cost-benefit analysis for small and medium-sized firms is still under development [43].

3. Research Methodology

This systematic review adheres to the PRISMA declaration's established guidelines. According to [44], it collects and analyses multiple research papers through three phases: planning the review by defining the objective, conducting the study with the relevant literature using inclusion and exclusion criteria, reporting the review results, examining scientific publications, and determining keywords. Figure 1 illustrates the literature review's objectives, methodologies, tools, and software.

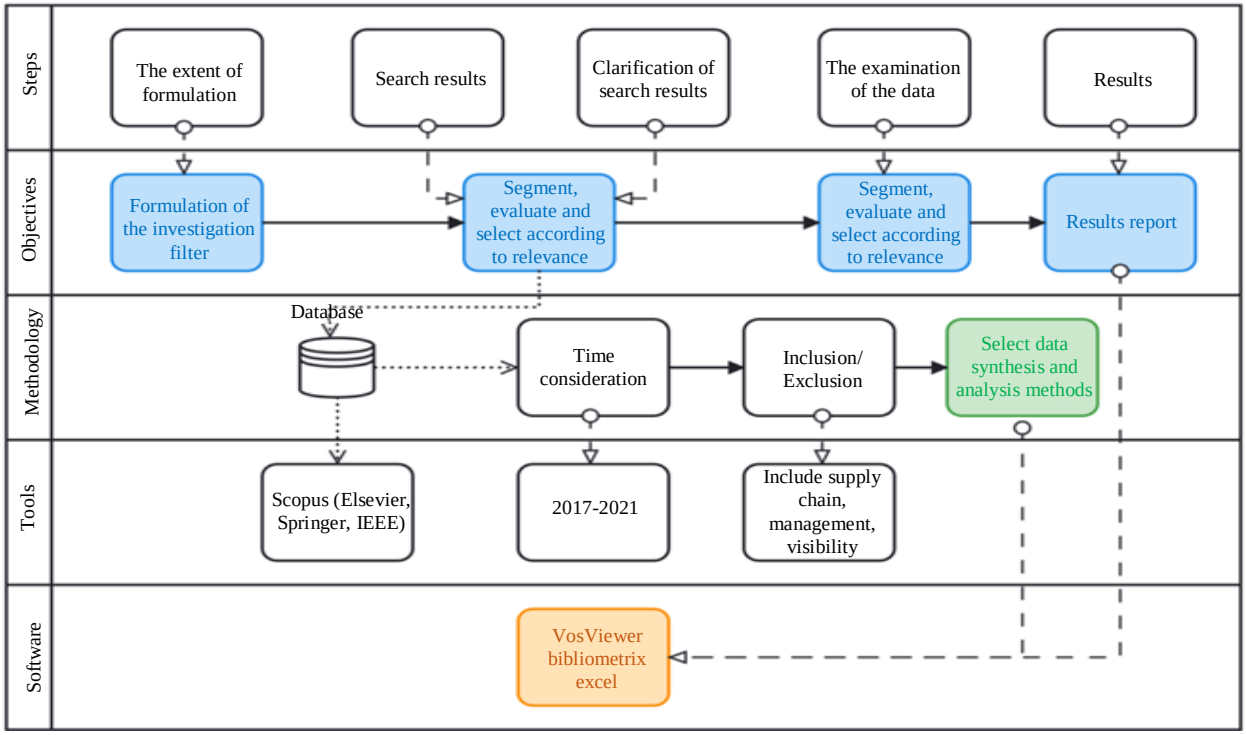

Fig. 1 Steps, objectives, methods, tools, and programs/software

Scopus was utilized to categorize research-related articles for article collecting. Elsevier, Springer, and InderScience are other publishers. The bibliometric study only included articles containing the keywords "RFID" and "Retail" from 2017 to 2021, the most significant and recent years of research. Additionally, "Inventory" and "Supply Chain" were used. From 2017 to 2021, the top 3002 keyword-based articles were related to supply chain (66.39%) and inventory (33.58%). (Refer to Table 1). Only final academic journal articles in english were evaluated in Table 2. The examination of 3002 products revealed duplicates. The search used "RFID" and "Inventory" again. The papers were extensively evaluated to eliminate duplication and ensure relevancy. Consequently, the search results were refined to eliminate duplicates and derive unique and pertinent papers. The search query was also limited to articles containing specific keywords. Table 3 displays the results.

Table 1. RFID retail journal articles

Themes in the Search Engines	Search String	Quantitative Findings from a Literature Review
RFID and Seller or Retail	RFID and Seller or Retail and PUBYEAR > 2017 and PUBYEAR < 2021	3002
RFID and Retail and "Supply Chains" or "Supply Chain"	RFID and Retail and PUBYEAR > 2017 and PUBYEAR < 2021 and (Limit-to (EXACTKEYWORD, "Supply Chains") or Limit-to (EXACTKEYWORD, "Supply Chain"))	1993
RFID and Seller or Retail and Inventory	RFID and Seller or Retail and (PUBYEAR > 2017 and PUBYEAR < 2021) and (Limit-to (EXACTKEYWORD, "Inventory"))	1008

Table 2. Bibliographic information on RFID, supply chains, and inventories is the overarching outcome

Bibliometric Data	RFID	Supply Chain	Inventory	Total
Final Publications	2853	1880	945	2825
Articles	1930	1342	678	2020
Journals	2200	1561	782	2343
Language - English	2964	1968	996	2964

Table 3. Using the more precise inquiry

Themes in the Search Engines	Search String	Quantitative Findings from a Literature Review
RFID and Seller or Retail and "Supply Chain" or "Supply Chain Management"	RFID and Seller or Retail and PUBYEAR > 2017 and PUBYEAR < 2021 and (limit-to (SRCTYPE, "j")) and (Limit-to (PUBSTAGE, "Final")) and (Limit-to (DOCTYPE, "ar")) and (Limit-to (Language, "English")) and (Limit-to (EXACTKEYWORD,"Supply Chains") or Limit-to (EXACTKEYWORD, "Inventory"))	188

3.1. Analysis of Statistical Data

Following database delimitation, 188 selected papers were statistically analyzed to identify and highlight trends among authors, journals, nations, and publication years (2017-2021). The number of articles generated in various countries is depicted in Figure 2 in proportion to the colour saturation of each nation. The results, which totalled 389 due to the 188 articles, are presented in Table 4. Of these, 201 were selected for their relevance to the study. The United States and India have the second and third most articles, respectively, after China. Most articles were collected from five periodicals, as shown in Figure 3. The quartiles of the remaining journals are shown in Table 5. Thus, the "International Journal of Production Economics," which focuses on engineering-management issues, published the greatest number of articles. Figure 3 shows that Choi, Tsan Ming (Choi, TM), an operations management professor at the National Taiwan University, has the most RFID papers with 9. Shen, Bin, and Gunasekaran, Angappa each have 5 RFID articles.

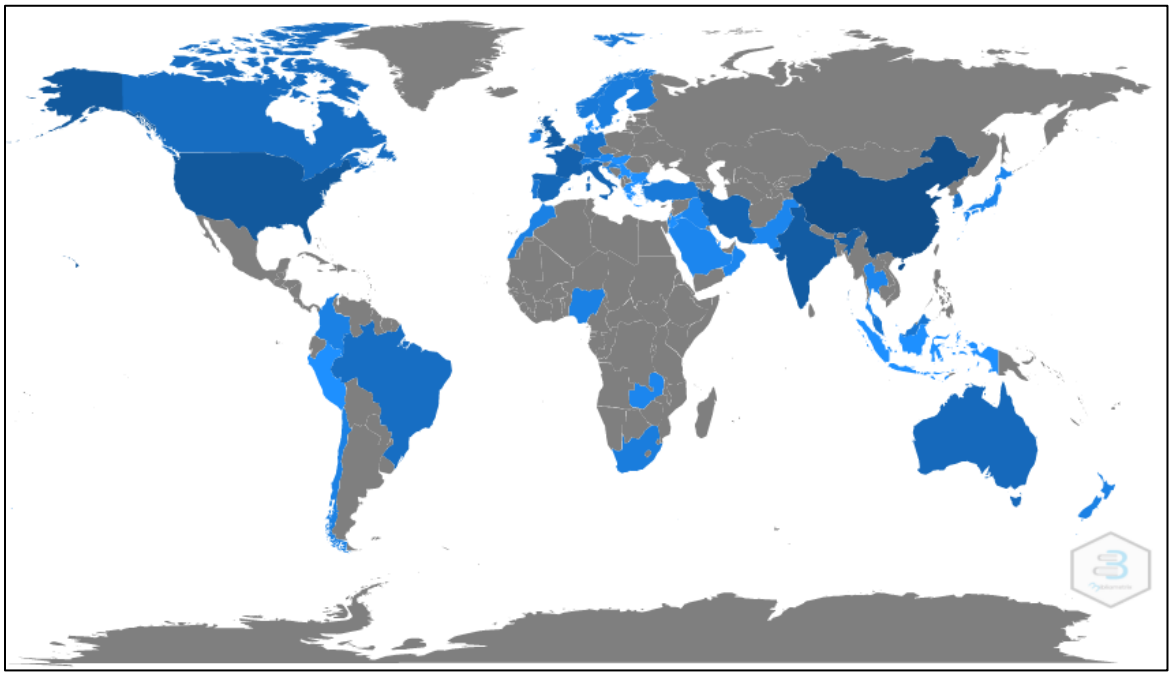

Fig. 2 A visual breakdown of where articles are written (explained in bibliometric)

Table 4. Numbers from figure 2

Nation	CHINA	USA	IND	UK	FRA	IRN	IT	SP
Article Count	139	61	47	45	31	24	23	19

Table 5. Articles per journal and per quartile

Journal	Articles	Quartile
International Journal of Production Economics	19	1
International Journal of Production Research	14	1
Journal of Cleaner Production	14	1
Computers and Industrial Engineering	9	1
IEEE Access	7	1
Sustainability (Switzerland)	6	2
European Journal of Operational Research	5	1
International Journal of RF Technologies: Research and Applications	5	3
Mathematical Problems in Engineering	5	3
Production Planning and Control	5	1
Technological Forecasting and Social Change	5	1
International Transactions in Operational Research	4	1

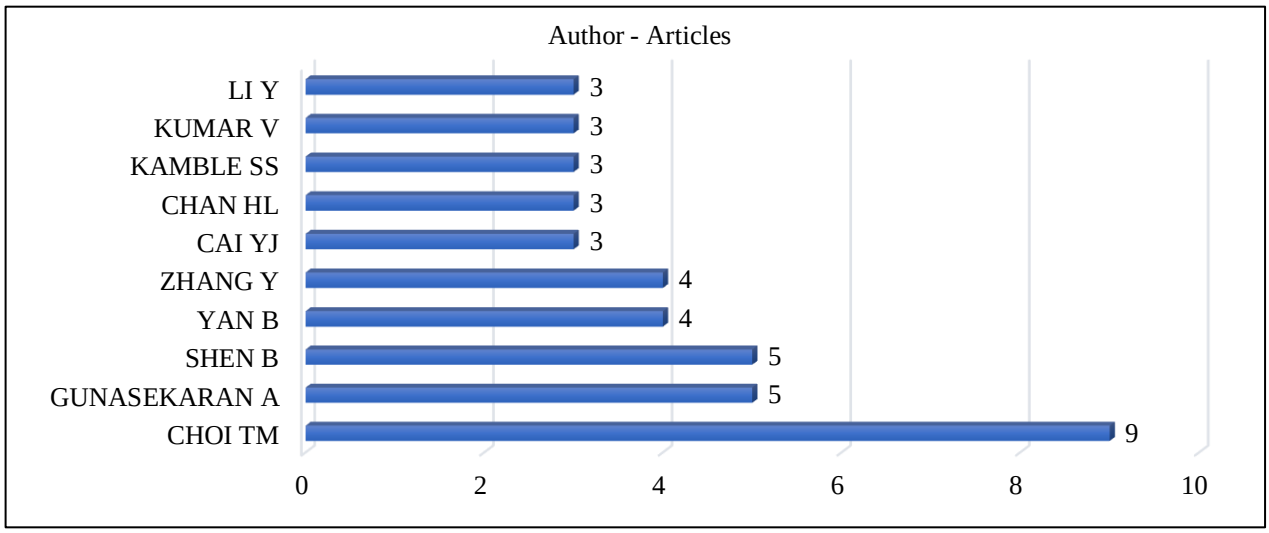

Fig. 3 Articles per author

3.2. Bibliographic Study

The bibliographic research was done using VOS viewer and bibliometrix. Both applications analyze and display data to monitor the evolution of indicators. As mentioned above, selected articles were in English and were final publications in an academic journal. This resulted in 188 papers with more than 2,600 authors and more than 10,000 keywords. Also, the link between the obtained keywords is depicted in Figure 4.

Clusters are keywords writers use more often; thus, we utilize this information to add new RFID research phrases. Table 6 shows that terms with at least 15 occurrences formed clusters with 16 more repeating keywords.

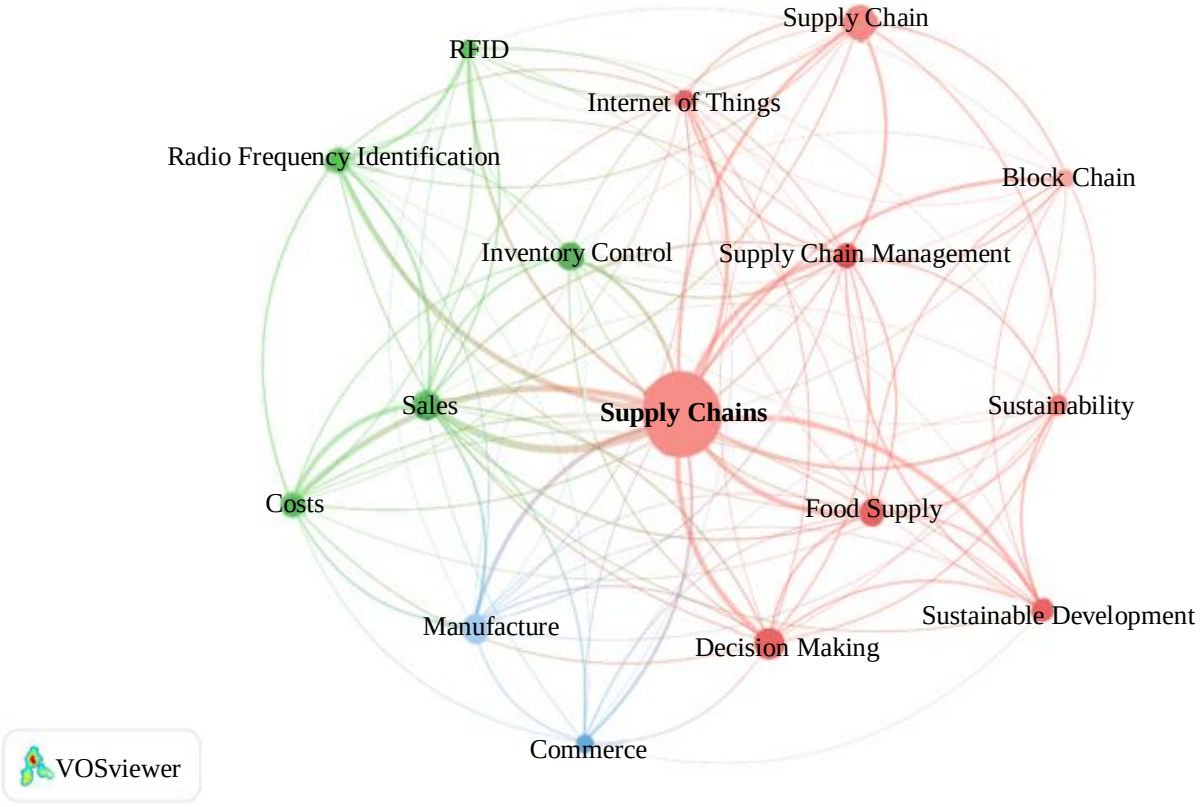

Fig. 4 Keyword match (elaborated in VOS viewer)

Table 6. Keywords occurrences

Keyword	Occurrences	Percentage
Supply Chains	175	28%
Supply Chain	59	9%
Sales	52	8%
Supply Chain Management	40	6%
Costs	36	6%
Radio Frequency Identification (RFID)	33	5%
Decision Making	32	5%
Food Supply	30	5%
Sustainable Development	27	4%
RFID	23	4%
Manufacture	21	3%
Internet of Things	21	3%
Sustainability	20	3%
Blockchain	20	3%
Inventory Control	18	3%
Commerce	15	2%

From the network shown in Table 6, it was possible to identify three main clusters, the first (Figure 5) was made up of 9 keywords, of which the most representative was “Supply Chain”; the second (Figure 6) cluster was made up of 5 keywords and “Sales” and “Radio Frequency Identification” were the most representative; finally the third cluster (Figure 7) was formed by only two keywords “Manufacture” and “Commerce”.

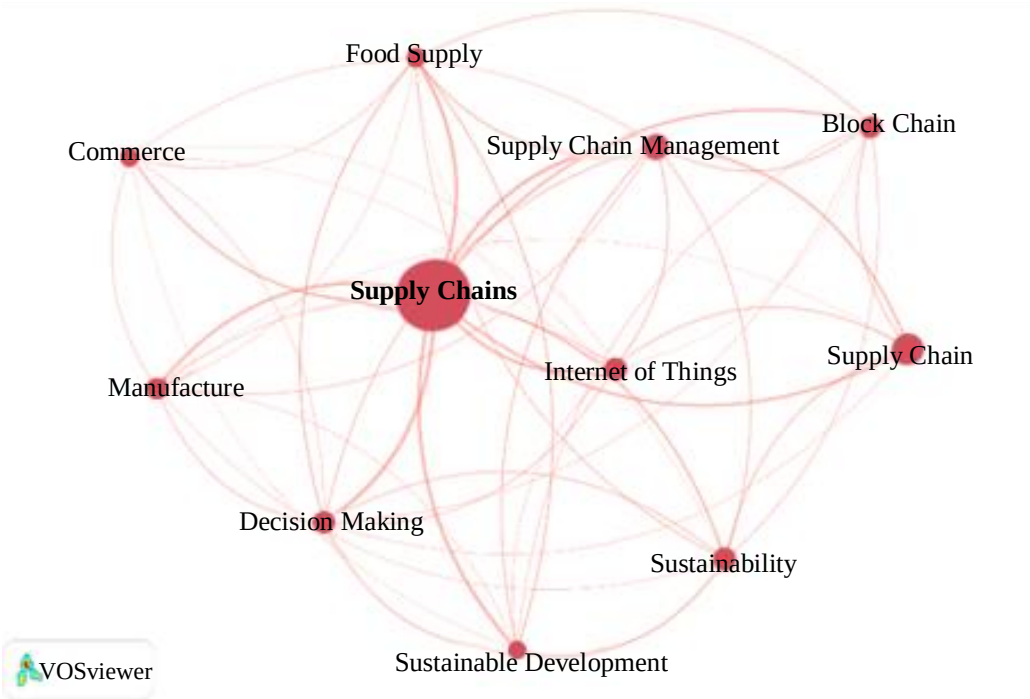

Fig. 5 Cluster related to supply chain (elaborated in VOS viewer)

This cluster suggests the relationship between "Blockchain", sustainability, the Internet of Things (IoT), sustainable development, decision-making, food supply, and supply chain, being the most representative and demonstrating the relationship between the other keywords.

Figure 6 shows us the relationship between RFID, Inventory control, sales, and costs, with sales being the main point of the relationship between the other issues; we can conclude that the variation in sales is related to the cost of implementing RFID for better inventory management.

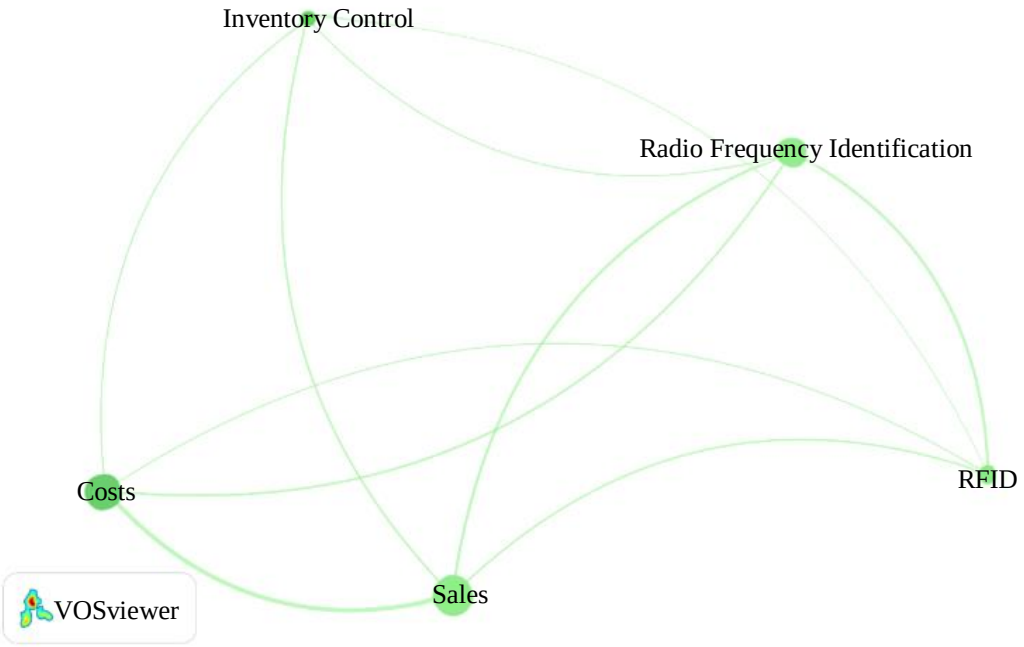

Fig. 6 Cluster related to sales and Radio Frequency Identification (elaborated in VOS viewer)

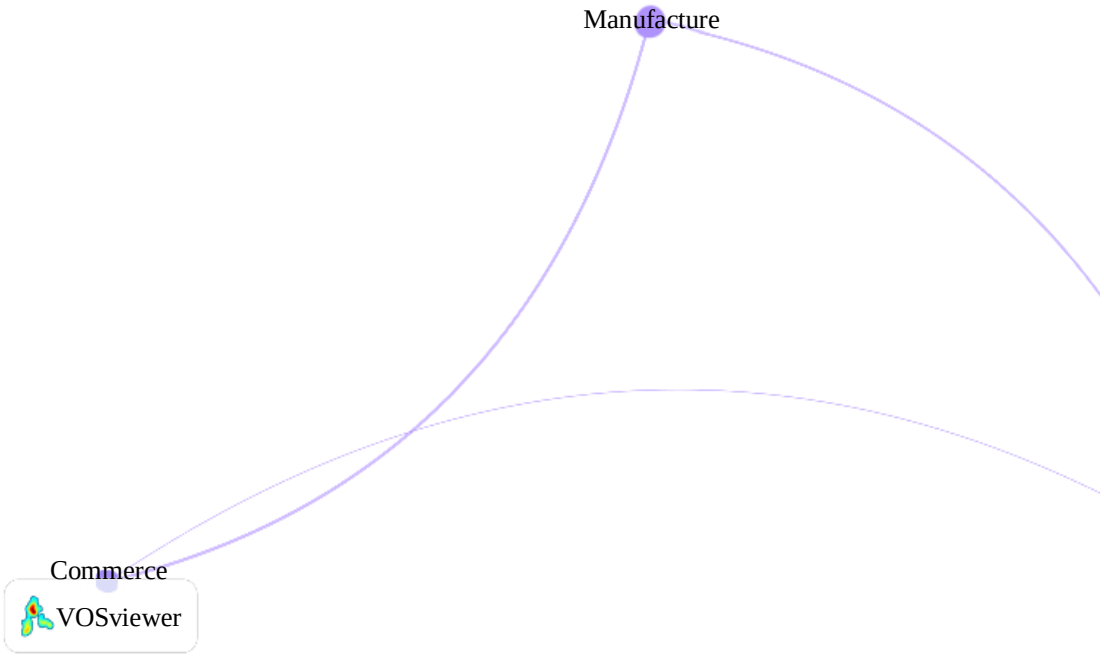

Fig. 7 Cluster related to manufacture and commerce (elaborated in VOS viewer)

When searching among the keywords, we find the last cluster of the relationship between manufacturing and commerce given by the growth of RFID. Figure 7 shows the close relationship between manufacturing and commerce.

4. Results and Discussion

Using VOS viewer and bibliometrix, the countries with the most production could be found, as shown in Table 4. Additionally, we identify the journal with the most output in Table 5. Finally, the authors in Figure 4 and the most valuable keywords are in Table 6.

4.1. Implications for Research

New studies in the same field and their connection with the SC show how RFID components interact in retail. The bibliometric analysis will help researchers identify SC efficiency and cost reduction research topics. The findings of this study have relevance for the analysis of RFID retail indicators and other indicators in inventory and supply chain management.

4.2. Consequences for Application

This research shows that businesses must consider the expenses of RFID implementation. RFID is mainly used for SC and inventory management. To have an indication, initiatives must identify advantages. The study examines RFID warehouse management indicators and their strengths and shortcomings. Thus, RFID is advised for companies in the recommended indicator range. Otherwise, weaknesses would affect cost-benefit analysis more. Finally, RFID and its retail applications are covered to better equip managers with the knowledge to develop and implement inventory management strategies that minimize costs and maximize efficiency. Therefore, it is helpful to grasp RFID indications for stock management.

4.3. Limitations

Study limitations exist. First, we only use Scopus, so we can't use other authors' documents from different databases. This bibliometric analysis excluded supplementary processes in books, papers, and journals since they diverged from the primary purpose.

By analyzing co-citation patterns, we may isolate the most relevant data and highlight the most crucial concepts related to the topic under investigation. Still, alternative conclusions may be derived while evaluating the huge database (more than 10,000 RFID articles). Co-occurrence and bibliography coupling analyses may give extra information. However, this research did not use these; therefore, publishing these findings may not be relevant.

4.4. Research Questions

We will now answer the research questions previously asked.

RQ1. Does current research explore the effect of RFID on reducing IRI?

The three most prevalent IRI issues are provisioning unavailable inventory and transaction failures. Transaction mistakes include delivery, scanning, shipping, and misidentification [45]. Shipping mistakes, such as deliveries to the wrong location or of the wrong goods, are expensive since consumers may seek a refund, and the supplier will have to pay extra to get the item returned [46]. Scanning errors, the most common error, in this case, is to speed up the checkout process; the cashier may inspect an item more than once as if they were the same, which leads to an IRI of both articles. Misidentification of items is generated by scanning errors-shrinkage errors (stock loss) cause the failure of ready-to-sell products.

Additionally, inaccessible inventory is when some products are not in the right place and are unavailable to customers. Numerous authors have studied inaccessible inventories, also called lost items. According to [47], the literature on supply errors is limited. Supply process, efficiency, and Product quality can affect inventory accuracy. In summary, RFID enables SC improvements against IRI by providing product traceability in real-time data.

RQ2. Is it possible to have an IRI of 0 using RFID?

No technology or process can accurately count warehouse units, and hand counting is not error-free. Even in a perfect environment, RFID technology's chip and antenna provide erroneous results [48].

However, not everything is a technology, which indicates that wisdom and ingenuity are similarly required. RFID can be combined with other elements to improve its performance, as presented with intelligent shelves; these shelves would have the reader incorporated, eliminating the need for human resources to point the reader and be able to send information each second instantly.

In the same way, robots can be used instead of people when moving around the warehouse and using the reader [49]. Additionally, we have voice assistants who use the information provided by RFID to locate the products and inform the operator of their location. Thanks to this, we can say that RFID technology is present in Industry 4.0 [50].

RQ3. Does current research explore the effect of RFID on increasing order variability with stable demand?

Over fifty years, the SCM has examined the bullwhip effect. As customer demand ripples through the SC, it grows (customer, retailer, distributor, producer, and supplier). Removing the bullwhip effect may boost profits by 15–30%.

The bullwhip effect is caused by SC information failures and material and information flow delays due to a lack of optimization in information sharing, cooperation, and communication [51]. Several authors believe AIS, like RFID, will reduce the bullwhip effect and boost SC efficiency. Improved inventory visibility provided by AISs reduces stockpiles of potentially dangerous items and the bullwhip effect [52].

RQ4. What were the limitations, consequences, or disadvantages when implementing RFID?

RFID saves time, money, and waste. Wal-Mart and Procter & Gamble increased service from 96% to 99% and decreased inventory by 70% after RFID installation.

Walmart gained these advantages over time, but initially, suppliers were inconvenient because RFID was costly and primarily borne by suppliers, while retailers benefited. Many studies tried to get suppliers to cover these costs, but Revenue Cost Sharing (RCS) worked well. Numerical analyses show that the RCS contract coordinates retailers' SC better than the WP when RFID is used at the item level. SMEs benefit most since they have a higher inventory registration error rate than large companies with a defined inventory system [53]. Product theft and human error cause missing tags in RFID-enabled supply chains and warehouses. MMTD is recommended.

RQ5. How much study has been done on RFID's potential uses in big, medium, and small businesses?

Large companies conducted more research than SMEs. However, RFID helped SMEs more with a system previously designed for IRI margin of error, product visibility, and traceability. RFID technology's product identification, connectivity, and real-time information benefit the supply chain. Blockchain is the newest addition to RFID, GPS, and IOT detection systems [54]. These devices transformed supply chain product and process monitoring. They have various issues with information security, standardization, inoperability, and large-scale player dispersal [55]. Blockchain technology may solve these inefficiencies by handling items without intermediaries or trusted persons [56].

Statistical analysis and bibliometric mapping were used to analyse and use data from citations and publications. The article's contributions, tools, software, major theories, subjects, methodologies, design, and quality were evaluated.

5. Conclusions

RFID positively affects efficiency and cost reduction when used in inventory management and the supply chain. Strategic management accounting practices may positively affect logistics providers' supply chain efficiency and profitability by fostering cooperation and coordination among them. The expansion of RFID is impacting the already tenuous relationship between production and trade. Decision-making is aided by understanding the key indicators RFID provides for inventory management. Limitations of this study include its selective database, lack of co-occurrence analysis, and inadequate citation of secondary sources. Managers may benefit from understanding RFID and its applications in the small business sector to develop and implement inventory management strategies that cut costs and boost efficiency.

The research reveals the interplay between the many RFID elements in the retail company by exposing fresh research opportunities in the same sector and their relationship to the supply chain. When determining the ROI of RFID, businesses must first decide what benefits will accrue from the technology's adoption. Identifying critical indicators for RFID-based warehouse management and their significance and limitations provides valuable data for making decisions. RFID for better inventory management is expensive, reflected in sales fluctuations.

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