

# Mapping of Warehouse Radio Frequency Identification Research: A Bibliometric Analysis

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## Abstract

Warehouses play a vital role as an intermediary between entities in supply chains, connecting upstream and downstream entities. Implementing Radio Frequency Identification (RFID) technology as a warehouse management system enables data collection with more accuracy, speed, and reliability. This research was motivated by the limited bibliometric perspective and visualization of research on warehouse RFID. The use of bibliometric methods aimed to find basic patterns and an overview of the direction of research related to warehouse RFID. This research utilized the Publish or Perish and VOSviewer tools for analyzing purposes. This study, comprised of 172 Scopus journals, provided an extensive overview of the developmental progress from 2003 to 2023. Bibliometric visualization was conducted to investigate the outcomes from later publications connected to warehouse RFID. The visualization displayed the leading publishers, yearly patterns, prominent publication titles, top authors, most referenced papers, distribution of keywords, most influential journals, and areas of research that require more investigation.

**Keywords:** Logistics, Optimization technology, Research mapping, RFID, VOSviewer

## 1. Introduction

Warehouses serve as a crucial intermediary between upstream and downstream entities within supply chains and have acquired a significant role in recent years [1]. The impact of warehouse performance extends beyond warehouse operating costs and productivity, including the entirety of the supply chain [2]. To enhance efficiency within the warehouse, it is crucial to get location data of all available resources promptly. This information is essential for ensuring precise decision-making throughout warehousing operations [3]. Therefore, integrating information technology (IT) becomes imperative to facilitate warehouse planning and control. IT developments, such as electronic data interchange (EDI), enterprise resource planning (ERP), warehouse management systems (WMS), and RFID, have been extensively utilized to facilitate warehouse operations, particularly in enhancing inter-warehouse collaboration [4]. RFID enables direct and accurate identification and tracking of objects without physical contact, whereas other IT solutions often rely on manual input or time-consuming barcode scanning. Thus, RFID has the advantage of increasing efficiency and accuracy in inventory management, goods tracking, and workflow management in warehouses. Among the various options available, RFID is considered the most productive technology in warehouse operations [5].

The recent developments in information technology, such as RFID and sensor technology, present a novel approach to establishing warehousing facilities. In warehouse operations, items may experience expiration, damage, and other conditions, potentially resulting in economic losses for enterprises. This inquiry pertains to effectively utilizing RFID and sensor technologies to facilitate warehouse operations [6]. RFID systems can identify multiple tags simultaneously; therefore, RFID will play an essential role in improving the competitiveness of logistics warehousing [7].

RFID is a prevalent automatic identification method without physical contact. It has found extensive application in various supply chain and warehouse management fields. A typical RFID system comprises costly, bulky readers and highly affordable, compact tags [8]. RFID technology is utilized comprehensively across diverse sectors like food and beverage, automotive, healthcare, and manufacturing. Implementing RFID technology in these businesses has yielded

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notable financial and technical performance enhancements [9]. Research Chen et al. [10] With RFID, the order collection process can be carried out more quickly and precisely because the system can automatically identify and track the location of goods in the warehouse. This reduces the time needed to search for and retrieve items and reduces the risk of human error in the process.

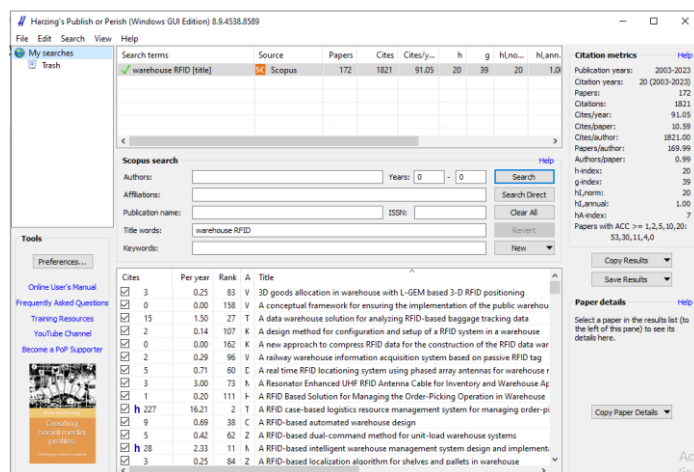
In warehouse operations, RFID enables tracking, sorting, inventory management, routing, retrieval, and distribution of objects throughout the system, regardless of physical location. One illustration of the application of RFID technology is its ability to transmit signals indicating the existence of items within a retail store. These signals convey various pieces of information, including the item's unique identity, storage location (such as the row, shelf, section, and rack), and any additional user-defined details on the object [11]. The warehouse system, which utilizes RFID technology, primarily comprises three components: warehouse management software, RFID hardware, and an RFID middleware system. Integrating these technologies enables the completion of numerous operations related to managing commodities within a warehouse [12]. The bibliometric perspective of RFID warehouses has received limited attention in existing research, thereby serving as the foundation for the present study.

Bibliometrics is an exploratory analysis using statistical techniques that allows the examination and quantification of a particular topic's development to evaluate previous research [13]. In addition, bibliometrics conducts a literature review by analyzing issues and clustering themes within a specific discipline, providing an agenda for future research [14]. Bibliometric analysis can be utilized to identify the most frequently used words/phrases in keyword lists [15]. The advent of logical databases such as Scopus and the Web of Science has facilitated substantial information collection [16]. Therefore, bibliometrics enables mapping primary themes when discussing RFID implementation in warehouses. Our study aims to fill a gap in the existing literature by conducting a bibliometric analysis specifically focused on warehouse RFID. This research provides valuable insights into current trends and addresses the lack of bibliometric articles. Our contribution lies in mapping RFID research in warehouses, clarifying its relevance and significance in advancing warehouse operations [1].

## 2. Literature Review

The first stage of this research used Publish or Perish (PoP) software to collect publications related to warehouse RFID. Then, the data obtained was processed and analyzed using Microsoft Excel to get graphic images and tables. Furthermore, VOSviewer is used to visualize article data in network form. VOSviewer software can visualize the development of publication trends related to RFID warehouses into a bibliometric map.

Articles were collected by searching the Scopus database from 2003 to 2023 to retrieve all available papers on warehouse RFID technology. The Scopus database has been acknowledged as an academic paper database for conducting systematic reviews [17]. The Scopus database was selected for the search due to its multidisciplinary nature and the presence of significant shared metrics that facilitate the comparison of academic findings. The papers collected using PoP software with the keyword "warehouse RFID" yielded 172 articles, as depicted in Figure 1. The conclusions were saved in the research information systems (.ris) format and analyzed in VOSViewer.



**Figure 1.** Search Results utilizing Harzing's Publish or Perish

The bibliometric analysis was conducted using the VOSViewer to examine the development patterns on the "Warehouse RFID." The acronym VOS in VOSViewer represents the concept of visualization of similarities. VOSViewer was utilized to do a systematic analysis aimed at discerning the intellectual structure and conceptual framework of the literature on the topic under review [18]. This software can support thousands of articles' analyses at once [19]. The analysis of clusters, which are collections of frequently used keywords, can highlight research areas within a given subject. VOSViewer can facilitate future researchers' endeavors to ascertain the trajectory of the study and acquire a comprehensive understanding of RFID in warehouses. The network, nodes, and keywords are represented on the map with varying dimensions based on their frequency and colored markers that indicate their membership in distinct clusters [20]. Using VOSviewer, search parameters, such as keywords, time range, and other constraints, were adjusted to select publications relevant to research on RFID in warehouses. Analysis criteria were applied, such as frequency of occurrence, relationships between keywords, and geographic or institutional distribution of included publications. With these settings and criteria, a more comprehensive visualization of research trends and patterns in the literature on RFID in warehouses can be generated, assisting readers in better understanding and interpreting the analysis results [21].

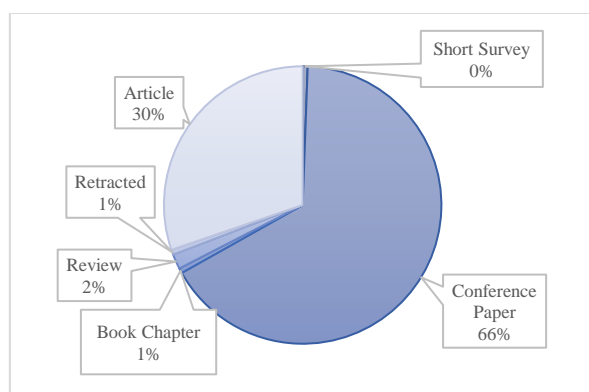
Bibliometric analyses can have limitations, including primary data that only includes some relevant publications and bias in data selection and interpretation. The sensitivity of keywords and search parameters was tested to increase clarity, and objective analysis approaches were considered. This is done to reduce potential bias and strengthen the validity of research findings [17].

### 3. Results and Discussion

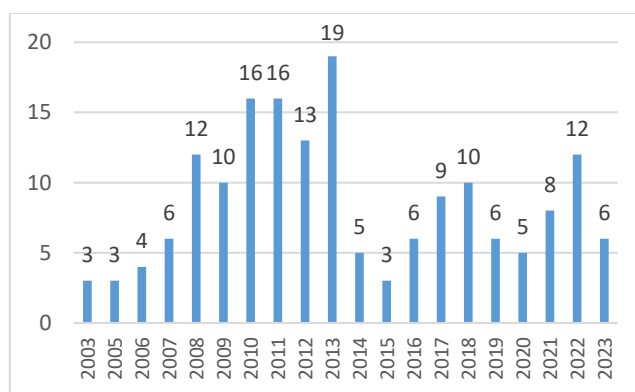
Science mapping is a method for visualizing the field of study of bibliometrics. Bibliometric analysis complemented by science mapping makes it possible to measure the intellectual structure of a field of research and its dynamics [21]. By understanding and integrating findings from various aspects of bibliometric analysis, Research Gaps can gain a more holistic understanding of research trends in warehouse RFID. This allows them to identify research priorities, direct their research efforts, and contribute more effectively to developments and innovations in the field [22].

#### 3.1. Bibliometric Analysis of Publication Output

A total of 172 publications about warehouse RFID were identified through PoP software. The classification based on the type of publications is depicted in Figure 2, while the distribution of publication years is illustrated in Figure 3. According to Figure 2, the data reveals that the most considerable portion of articles consists of research papers, precisely 66% ( $n = 114$ ) "conference papers," followed by 30% ( $n = 52$ ) "articles." Review papers published within the past decade accounted for only 2% ( $n = 3$ ) of the total articles.



**Figure 1.** Publication Type



**Figure 2.** Publication year

There was a steady and significant growth in the number of publications during the first decade, followed by fluctuations during the second decade. In 2003, there were three (1.75%) publications, which had a substantial increase until it reached a peak of 19 (11.05%) publications in 2013. In 2015, there was a notable decline in the number of

publications, with only three papers (1.74%) published. The number of publications in the subsequent years fluctuated until it reached 10 (5.81%) publications in 2018 and 12 (6.98%) in 2022.

### 3.2. Bibliometric Analysis of Citation

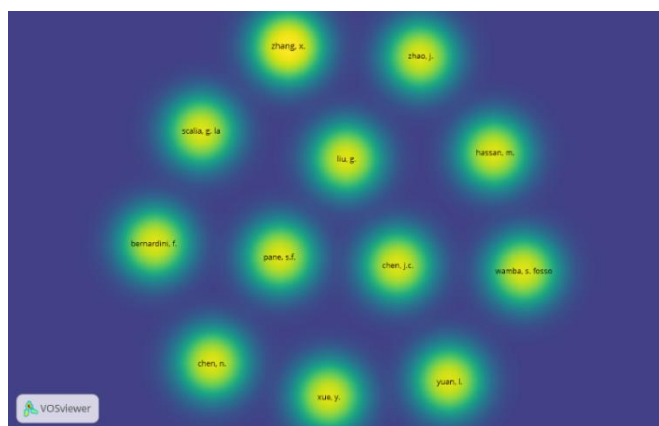
Citation analysis is considered an essential characteristic of academic research. It can be based on three sources: cited documents, cited sources, and cited authors [23]. This study focused on document citation. Citation analysis provides an overview of the most cited papers and the relations among papers [24]. Citations refer to texts that contain cited references, thereby encouraging a dynamic vision of the development of the topic under review [26].

Using PoP software for document analysis yielded 172 publications. Among these, 24 publications (equivalent to 20% of the total) were authored by a single individual, while the remaining 162 publications (constituting 80% of the total) were produced through authors' collaboration. The dataset has a cumulative count of 1823 citations, with an average annual citation of 214.16. In addition, the number of citations per article was 10.61. The average number of citations per article was calculated by dividing the number of citations and the total number of publications. On the other hand, the average number of authors per publication is 0.93, which indicates the extent to which an author or journal publishes self-authored or co-authored articles.

Chow et al. [25] published the most cited paper in the article "Design of an RFID case-based Resource Management System for Warehouse Operations" from the Journal Expert System with Applications in 2006. Since its publication, the document has obtained 285 citations, an average of 16.76 per year. In addition, the analysis of 172 articles revealed that most papers were received from Advanced Materials Research and Applied Mechanics and Materials; both had seven articles. This paper became popular as it contributed by proposing an innovative solution for case-based resource management in warehouse operations using RFID technology. Additionally, some other influential documents in the warehouse RFID domain include "An RFID case-based logistics resource management system for managing order-picking operations in warehouses," "An RFID based solution for managing the order-picking operations in the Warehouse," and "A design method for configuration and setup of an RFID system in a warehouse." A brief analysis of these papers will provide deeper insight into the development of concepts, technologies, and applications in warehouse RFID and help identify key trends in research in this domain.

### 3.3. Bibliometric Analysis of Co-Authorship

The bibliometric mapping using the VOSviewer is depicted in Figure 4. The dimensions of the author's label were based on the quantity of articles published. To prevent the repetition of titles, several authors' nameplates were omitted. The luminosity of the yellow light depicts the density of clusters. The yellow tint on the map corresponds to the quantity of things associated with other objects. Zhao & Zhang [1] have the lightest node density color, which indicates that Zhao & Zhang [1] conducted research by citing several studies beside him as a form of collaborative research on warehouse RFID. In the past 20 years, Zhao & Zhang [1] have published the most papers, totaling three. Potential collaboration opportunities open up opportunities for more diverse and innovative research and strengthen relationships between researchers in warehouse RFID.

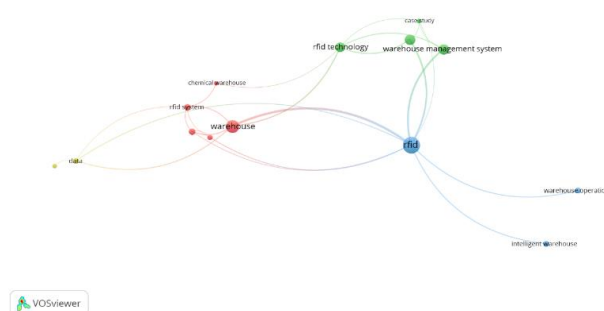


**Figure 3.** Co-Authorship Visualization

### 3.4. Bibliometric Analysis of Co-Occurrence

This phase aims to evaluate documents' substance, structures, and patterns by quantifying their significance and tallying the occurrence of keywords in the examined articles. The paper "RFID Warehouse" in the Scopus database yielded 172 keywords. According to the VOSviewer computation, 377 terms are considered essential, as shown in Figure 5.

Keywords with more excellent dimensions reflect their higher frequency of usage in titles related to warehouses. Figure 5 displays the keywords with high frequency about warehouse RFID. The line graph demonstrates a positive correlation between the keywords, indicating that the words in the title are a perfect fit. The most often occurring keywords are "RFID" with a frequency of 89, "warehouse" with a frequency of 45, "warehouse management system" with a frequency of 26, "warehouse management" with a frequency of 25, and "RFID technology" with a frequency of 23. The implication is that Future research could focus on developing more advanced RFID technology to improve inventory tracking, stock management, and overall operational efficiency in warehouse environments.



**Figure 4.** Keyword co-occurrence map

Table 1 shows the keyword clustering results in the reviewed papers' titles. Each cluster has different keywords, indicating the diverse range of research in warehouse RFID applications. According to Table 1, clusters 1 and 2 have the most significant number of keywords, with 5 and 4 words, respectively. Researchers in the RFID warehouse pay more attention to the keywords found in clusters 1 and 2. This finding indicates that the keywords in these clusters have obtained greater attention from researchers in the past two decades.

**Table 1.** Clustering based on keywords in the title

Cluster	Number of keywords	Selected keywords
1	5	Chemical warehouse; localization; RFID system; warehouse; warehouse environment
2	4	Case study; RFID technology; warehouse management; warehouse management system
3	3	Intelligent warehouse; RFID; warehouse operation
4	2	Data; RFID data warehouse

## 4. Conclusion

Bibliometric analysis facilitates the exploration of essential keywords in each study and the extent of knowledge and aids in detecting the distinctiveness of previous studies. According to the bibliometric evaluation from the Scopus database, this paper analyzed 172 articles focusing on RFID warehouses. Most articles were research papers, consisting of 66% (n = 114) "conference papers" and 30% (n = 52) "articles," while "review papers" published within the past decade accounted for only 2% (n = 3). There was a steady and significant growth in the number of publications during the first decade, with the peak in 2013 accounting for 19 articles, followed by fluctuations during the second decade. The number of citations accumulated was 1823 or 214.16 per year.

Furthermore, the publication's citation rate stood at 10.61, and the average number of authors per publication was 0.93. As observed through publication visualization, the bibliometric analysis yielded insightful findings regarding RFID warehouses. By leveraging these findings, practitioners can improve RFID system design and implementation, select

appropriate technology, and optimize warehouse infrastructure to increase operational efficiency. Chow published the most cited paper with 285 citations, an average of 16.76 per year. In addition, the analysis of 172 articles revealed that most papers were obtained from Advanced Materials Research and Applied Mechanics and Materials; both had seven articles.

On the other hand, in the past 20 years, Zhao & Zhang [1] have published the most papers. There are four groups of keywords, each with different keywords, reflecting the main themes in research on RFID in warehouses, such as RFID technology, warehouse management systems, RFID applications in supply chain management, and other related logistics aspects, showing the diversity of research in warehouse RFID applications. However, it is essential to note that this research also has certain drawbacks. Papers obtained from the Scopus database for subject trend analysis were limited to their titles; this could introduce potential bias and limit the completeness of the data we analyzed. However, by recognizing these limitations, we sought to increase the credibility of the study's findings and conclusions. Future research could consider including abstracts or keywords to address this for a more holistic analysis. Alternatively, databases or sophisticated text-mining techniques can provide deeper insights. Additionally, by using alternative databases or advanced text mining techniques, researchers can explore deeper potential areas for further research in warehouse RFID.

## 5. Declarations

### 5.1. Author Contributions

Conceptualization: W.A., Q., D.S., and J.N.E.; Methodology: Q.; Software: W.A.; Validation: W.A., Q., D.S., and J.N.E.; Formal Analysis: W.A., Q., D.S., and J.N.E.; Investigation: W.A.; Resources: Q.; Data Curation: Q.; Writing Original Draft Preparation: W.A., Q., D.S., and J.N.E.; Writing Review and Editing: Q. and W.A.; Visualization: W.A. All authors have read and agreed to the published version of the manuscript.

### 5.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

### 5.3. Funding

The authors received financial support for the research and publication of this article from the Department of Industrial Engineering, Faculty of Industrial Technology, Universitas Islam Indonesia, Yogyakarta, Indonesia.

### 5.4. Institutional Review Board Statement

Not applicable.

### 5.5. Informed Consent Statement

Not applicable.

### 5.6. Declaration of Competing Interest

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

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