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RESEARCH PAPER

# Class-Based Storage: Bibliometric Analysis for Research Mapping

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**ABSTRACT**

*This research aims to determine the scope and pattern of research and understand trends in class-based storage research to deliver the latest research on the topic of class-based storage for future studies. This study is based on data derived from several journal publications, limited only to publication years of 2012 to 2023. Harzing's Publish or Perish and VOSviewer software were used in data collection. Therefore, 980 articles were obtained based on keywords and processed by using bibliometric analysis. From the results of bibliometric research on the topic of class-based storage, identification of trends and patterns on research growth is obtained, analyzing renewal, obsolescence, and distribution of references, estimating productivity, author, year of publication, most-contributed publishers, and collaboration among authors who were discussing interrelated topics. This research shows that in bibliometric studies in class-based storage literature, by involving analysis through keywords contained in titles and abstracts, as well as various analyses of years of publication, most publications are able to deepen and expand the literature in the previous class-based storage-related research. So that the findings, in terms of assessment techniques and relationships, can be used as information for future researchers in such fields of study. Research on bibliometrics is the main reference, especially in the arrangement of facility layout and warehouse management. The originality provided by this study lies in the presentation of differences and similarities between current and previous researchers and the processing of publication databases based on class-based storage journals. So that all published information on the topic of class-based storage in the last 10 years (2012-2023) could become a basis and reference for further research.*

**KEYWORDS:** *Bibliometrics; Logistics; Storage system; VOSviewer; Warehouse.*

## 1. Introduction

The main challenge for today's modern companies is to balance the achievement of competitive advantage with sustainability while meeting various expectations of stakeholders to maintain reputation, legitimacy, and credibility [1]. Competition in the business world is now getting fiercer, and every business is required to conduct business activities effectively and efficiently. Industrial companies in Indonesia need to have the flexibility to make changes so they can win world competition. The layout design influences the success of a factory planning project significantly [2]. Optimization of a warehouse in a loading unit is crucial so that total travel costs can be minimized, and it is critical to its operational efficiency, which is an important part of the supply chain. One of the findings is the importance of optimizing classes depending on warehouse utilization [3].

A warehouse is one of the important aspects owned by the company. The warehouse is a space to keep the goods, both raw materials designated for the manufacturing process and finished goods that are arranged for marketing [4]. The punctuality and sufficiency of raw materials can affect the smooth production process. Therefore, a good storage layout system and planning are required in the warehouse. The reason why the warehouse is called important is that the warehouse is also known as a buffer or balancer between supply and demand. Balanced supply and user demand are frequency stability symbols in a power system [5]. Traditionally, once the system

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frequency diverges from the tolerable range, the conventional unit has to alter its output to minimize the momentary discrepancy between generation and load [6].

Warehouse layout is a problem that is often experienced by the industry; this problem will lead to inefficient goods loading and unloading processes. When goods are situated far from the warehouse door, it will require substantial costs to move the item. The available space can be utilized effectively by a good warehouse storage system to increase space utilization and minimize material handling costs. The arrangement of paths, aisles, and passageways in this storage system affects storage space utilization and material handling costs [7]. The arrangement of paths, aisles, and passageways in this storage system affects storage space utilization and material handling costs [8]. Related studies identify that an effective layout can decrease factory operating costs by up to 30% [9].

Parameters for a good raw material warehouse layout are the maximum fulfillment of space and faster completion of raw material requests [10]. The class-based storage method is one of the alternatives for facility layout that can improve the warehouse function in the production process. The class-based storage method is a compromised policy that ranks SKUs into product classes based on appropriate criteria such as volume or level of use [11]. Class-based storage with three classes is often denoted as ABC storage [12]. The class-based storage method is a procedure that classifies materials in warehouses into three classes, namely Class A, Class B, and Class C, based on Pareto's law with consideration of storage and retrieval (S/R) level activities in warehouse activities [13].

Of the many studies related to warehouse layout, especially discussing layout arrangement using class-based storage, there is less research from the perspective of class-based storage of a bibliometric. So bibliometric research on class-based storage becomes crucial. Bibliometrics can be interpreted as the activity of measuring or analyzing books or literature using a mathematical and statistical approach [14]. Bibliometrics is a quantitative technique for identifying patterns of publication authorship, citations used for subjects, collaboration patterns, research constituencies, and exploring the intellectual structure of specific domains in the existing literature [15]; [16].

Bibliometrics has become popular for identifying major journal trends on specific topics, widely cited papers, authors, institutions, and countries [17]. Bibliometrics is an extensively-practiced approach to tracking the structure of research field information and is used to analyze research topics [18]. By using this method, this study targets to recognize patterns and directions of class-based storage research and to find out the development of class-based storage research trends. This study is expected to fill in the theoretical gap due to the absence of bibliometric class-based storage-related articles. Bibliometric and research mapping are applied in an integrated way to describe the latest scientific studies about class-based storage. The importance of employing bibliometric analysis and research mapping techniques over others is to assist the researchers in composing the references to support class-based storage analysis.

## 2. Literature Review

### 2.1. Class-Based storage

The warehouse that uses the class-based storage method by [19] indicates warehouses with high transactions are suitable for this method. The method of class-based storage is the placement of materials or similarity-based materials or materials belonging to a group. The similarity of materials or grouped materials can be identified in the form of type similarities of items or similarities in a list of consumer orders [13]. The class-based storage method is suitable for warehouses that have a lot or almost thousands of materials. Later, this method is applied to optimize the distance factor and retrieval time. The fast-moving movement materials must be placed close to the I/O Point to reduce the occurrence of material movement [4].

As a general comparison, special storage is dedicated to placing dense, high-demand goods near I/O points, making them more material-handling friendly compared to arbitrary policies. On the other hand, more storage spaces are needed to deal with the maximum inventory level of each product in a prearranged location. Class-based storage is a compromised policy that attempts to associate the benefits of both policies [11]. Class-based storage is a storage policy that separates it into three groups, class A, B and, C, based on Pareto law by considering the Storage and Retrieval (S/R) activity level in the warehouse, 80% of S/R activities are distributed to 20% of items, 15% on 30% of items, and lastly, 5% of S/R activities are delivered to 50% of items [4]. Based on the method of class-based storage as well as the layout of existing facilities in the raw material warehouse, more flexible space is obtained by separating the area into several sections of

material space, class-based storage method creates more flexible space by dividing the area into several parts of the material space [13]. Thus, the order processing time is reduced, and all downstream processes attain benefits accordingly. Labor costs are reduced, and delivery reliability increases [20].

## 2.2. Bibliometric analysis

Bibliometrics is a systematic method that is extensively used to appraise research results to analyze related literature through the use of mathematical and statistical approaches [21]. In other studies, it is said that bibliometric analysis is a field of library and information science research that studies bibliographies using quantitative or qualitative methods [16]. Bibliometric analysis has been used in many scientific areas to map literature, reveal the history of the research field's development, and evaluate the productivity of scientific research by researchers, organizations, countries, and journals [22]. It is considered important because the results of the analysis can provide insights on related topic updates that go far beyond the scope of pre-existing journals.

Bibliometrics, on the other hand, is a quantitative statistical technique that uses mathematical, statistical techniques to assess the distribution of science articles, in which the publication growth rate is rapidly increasing [23]. In bibliographic analysis, it is necessary to extract some bibliographic-related data to abstracts, credentials, keywords, and other relevant information using different keywords combination [24]. The investigation of studies in a bibliometric analysis cannot be homogeneous. Besides, the bibliometric analysis only emphasizes on quantitative assessment of article attributes (namely, publications, citations, keywords, contributors, and publishers) and their relationship to one another [25].

In research conducted by [26], it was stated that bibliometric indicators appear as complementary, cheaper, and more objective in evaluating complex academic scenarios as a result of this growing professionalization. Following the bibliometric concept, an increase or decrease in the number of circulated scientific papers is a respected indicator of scientific developments in a certain field [27]. Therefore, to perform bibliometric analysis, various software tools were used to execute the bibliometric analysis: Bibexcel, Biblioshiny, BiblioMaps, CiteSpace, CitNetExplorer, SciMAT, Sci2 Tool, and VOSviewer [28].

## 2.3. Research mapping

A systematic mapping study or scoping study is intended to provide an outline of a research area through the classification and contributions calculation concerning the classification category [29]. In another study, it was stated that mapping is an analysis that identifies not outcomes but associations and focuses on features such as where the activity occurs, the source of funds, and the kinds of journals or media presented [30]. Mapping studies are suitable for comprehensively reviewing the literature in topic areas where many papers are available [31]. Research on mapping aims to reveal the structure and dynamics of scientific studies [32]. Mapping studies identify current systematic maps and evaluate them concerning the investigated topics, the frequency of publication over time, the place of publication, and the process of the mapping study [33]. This research process uses PoP and VOS viewer software for journal publication with the topic of class-based storage in the past 10 years, 2011-2023.

## 2.4. Research methods

The bibliometric analysis is employed in this study using a database of various publications in Google Scholar with the distribution of publication years in the last 10 years, namely 2011-2023. The selection of Google Scholar is based on a higher indicator score of 30% compared to Web of Science [34] and around 15% higher than Scopus. Google Scholar is more flexible and more general because it is freely accessible, and each author designs his own academic profile [35]. Google Scholar can effectively recognize highly cited documents which, combined with Google Scholar's unique coverage (no limitations on type and source of the document), make it an academic search engine as a supportive tool for bibliometric research correlated with the most influential scientific document identification [36]. Google Scholar displays considerable stability over time [37].

Data collection in this study was carried out by using Harzing's Publish or Perish (PoP) software. The existence of automatic citation counting software makes it easy to use citation metrics in the performance assessment of many academics [38]. PoP software can assist researchers in issuing distinguished journals. PoP can become a measurement of how knowledge is defined and evaluated [39]. The stages in this study were carried out first using the Publish or Perish (PoP) software to collect publications related to class-based storage. Then the data obtained were processed and analyzed using Ms. VOSviewer,

which was applied to visualize article data in the form of a network. VOSviewer is a software tool for generating and visualizing bibliometric networks. VOSviewer is applied to map and visualize networks, identify the structure of study areas, classify publications, and analyze grouping solutions produced [40]. Research concept is shown in Figure 1.

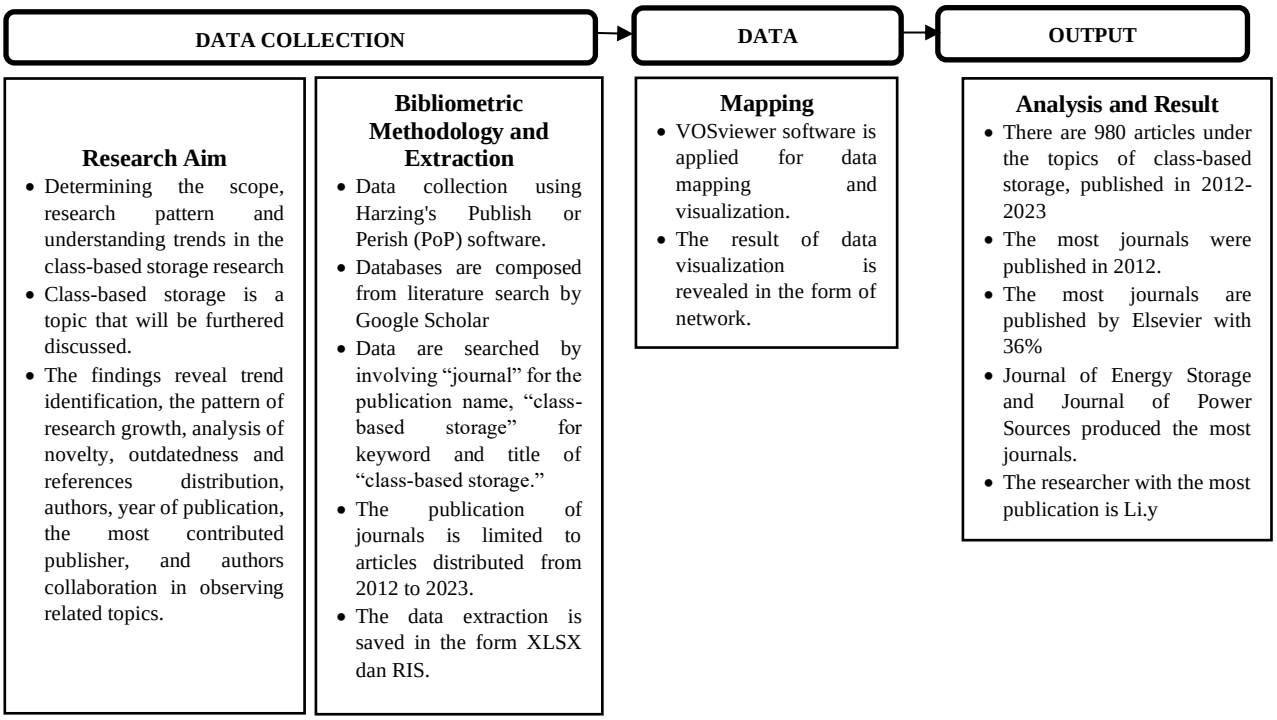


**Fig. 1. Research concept**

In this study, the name of the publication uses "journal," and the keyword uses "class-based storage." Based on the criteria found with the help of PoP software to track the Google Scholar database and to show the results of the search. Furthermore, the data obtained from PoP tracking are used to process and analyze class-based storage topics. The results come up with 980 journal articles that match the keywords and will be treated to the next stage, as shown in Figure 2.

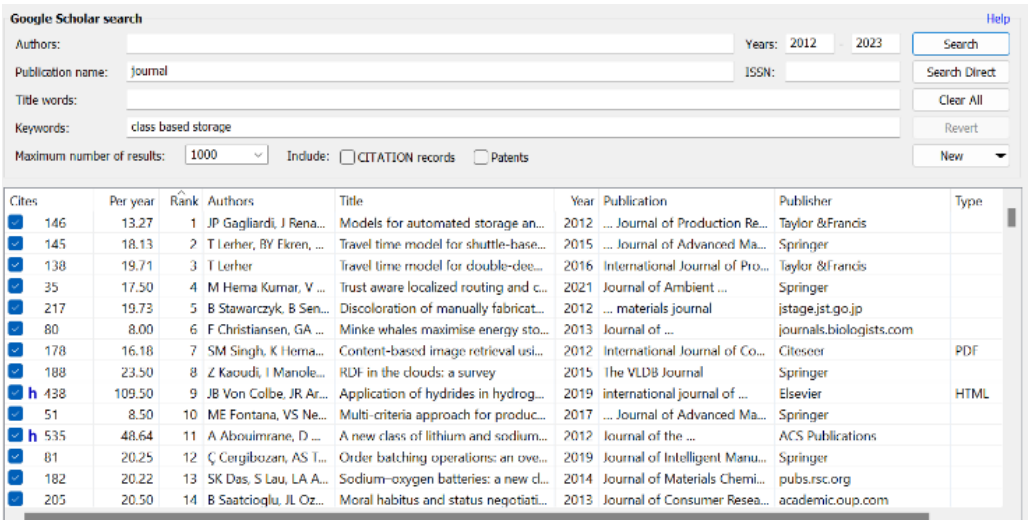


**Fig. 2. PoP software visualization with keyword**

By adding the keyword "class-based storage" to the title, as shown in Figure 3, only 33 articles were found on Software PoP that matched the keywords.

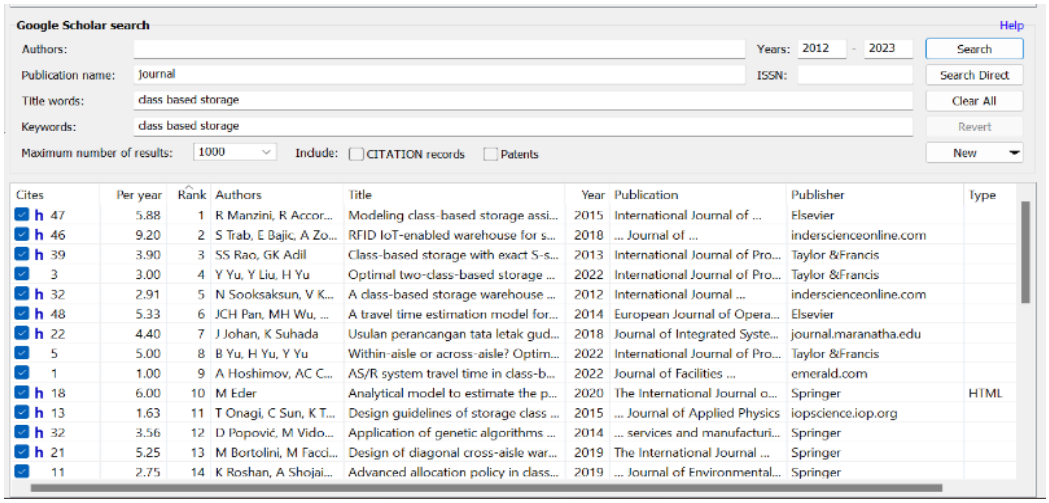


**Fig. 3. PoP software visualization based on title**

Bibliometric analysis can be performed with VOSviewer software. VOSviewer software is utilized to reinforce clustering and visualize the results of the co-occurrence study of high-frequency keywords [40]. VOSviewer software can visualize the development of publication trends related to class-based storage into a bibliometric map.

## 3. Results and Discussion

The bibliographical analysis is the actual citation count showing how many times an article is cited by other documents. Based on the current indexing, the system gets the number of citations from the reference section citing documents [41]. Bibliometric analysis is a powerful mapping tool to quantitatively measure scientific production [42]. Bibliometric analysis through scientific mapping provides in-depth analysis, pinpoints intellectual structures, and identifies hot topics using landscape maps [43]. In this results section, a graph of the mapping results of 980 class-based storage articles will be displayed to reveal the results of the meta-analysis. Keywords are used in mapping to group significant or unique terms in a publication with a similar theme of class-based storage. The results and discussion can represent research on developments and a research trend with the topic of class-based storage. Therefore, it can become a reference and opportunity for future research.

### 3.1. Publication output

There are 980 class-based storage-related publications, derived from a database search on Google Scholar, that was published in the period 2012-2023 from multiple different sources. The selection was performed in 2023, but this research was conducted in the 2nd month of 2023. Researchers want to analyze the latest developments in class-based storage when the economy has recovered from the Covid-19 pandemic, which can be seen from the decrease in the number of studies related to class-based storage from year to year. The distribution of publication years is illustrated in Figure 4.

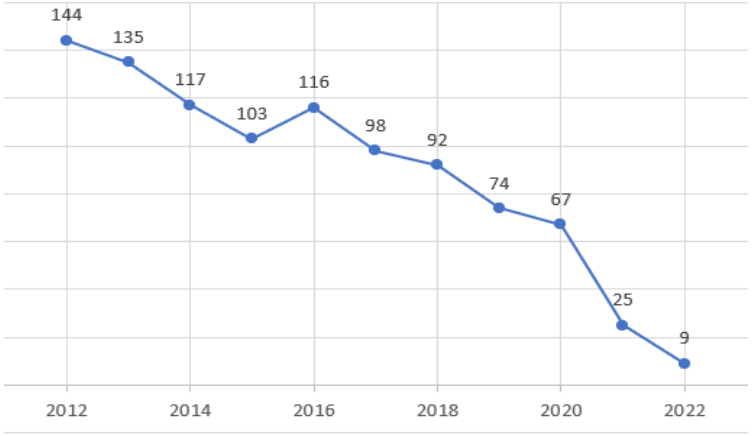


**Fig. 4. Publications per year**

From the analysis results of 980 publications identified on Google Scholar, VOSviewer reads

that class-based storage publications have decreased year by year. The most increased publications were in 2012, with 144 publications. However, in 2022 it experienced a rapid decline because only 9 publications were found that matched the keywords in the PoP software. The decline in publication level occurs due to poor research productivity in Indonesia since teaching activities in universities are more focused on the learning process than research. The existence of the pandemic period required the company to prioritize massive sales due to the economic crisis and put aside effective and efficient spatial layouts so that publications related to class-based storage topics decrease every year.

The next analysis highlights the publishers' distribution, as shown in Figure 5, taken from most of the publishers. Some of the publishers who contributed to this study were identified from the biggest or most well-known among researchers, namely publishers from Elsevier contributing 36%, pubs.rsc.org by 11%, Springer by 9%, Wiley Online Library by 7%, Taylor & Francis and a collection of publishers who publish journals only once in a certain period contribute 5%. In this study, the above publishers issued more publications than other publishers. Other publishers were classified as publisher groups that contributed less than 5%.

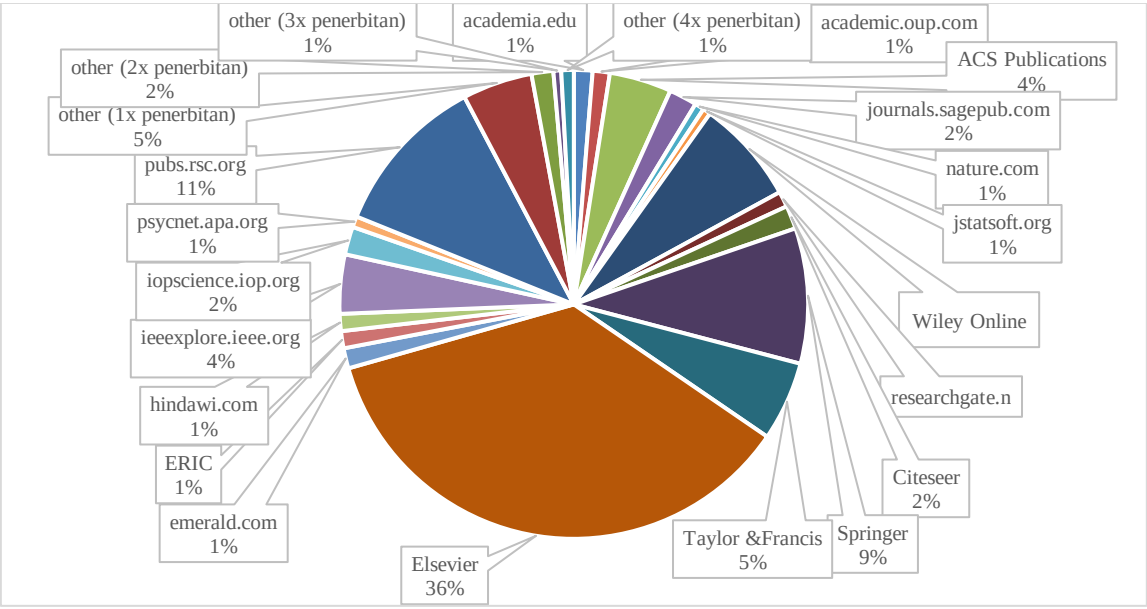


**Fig. 5. Publication by publisher**

Details of the frequency and percentage of publishers in the publisher mapping can be seen in Table 1.

**Tab. 1. Detail of publisher's frequency and percentage**

| Publisher | Frequency | Percentage |
|---|---|---|
| academia.edu | 12 | 1% |
| academic.oup.com | 11 | 1% |
| ACS Publications | 40 | 4% |
| journals.sagepub.com | 18 | 2% |
| nature.com | 6 | 1% |
| jstatsoft.org | 5 | 1% |
| Wiley Online Library | 67 | 7% |
| researchgate.net | 10 | 1% |
| Citeseer | 15 | 2% |
| Springer | 87 | 9% |
| Taylor &Francis | 51 | 5% |
| Elsevier | 336 | 36% |
| emerald.com | 13 | 1% |
| ERIC | 11 | 1% |

| Publisher | Frequency | Percentage |
|---|---|---|
| hindawi.com | 11 | 1% |
| ieeexplore.ieee.org | 38 | 4% |
| iopscience.iop.org | 18 | 2% |
| psycnet.apa.org | 7 | 1% |
| pubs.rsc.org | 104 | 11% |
| other (1x publish) | 45 | 5% |
| other (2x publish) | 14 | 2% |
| other (3x publish) | 5 | 1% |
| other (4x publish) | 8 | 1% |

### 3.2. Bibliometric analysis

Based on a search using PoP software, 980 publications were generated that match the keyword "class-based storage." It is revealed that the total citations reached 353 publications. Document search results using PoP were obtained with total citations of 282332 citations, citations per year counted as 25666.55 citations, the number of published citations is 288.09, and the average number of paper authors is 3.63. The most cited publication is written by A Geiger, P Lenz, C Stiller, et al. entitled Vision meets Robotics: The kitti dataset" in the journal The International Journal of Robotics Research [44]. Since its publication in 2013 until now, a total of 6791 articles have been cited, with an average of 679.10, annually. Out of 980 documents, the most published articles are derived from the Journal of Energy Storage, Journal of Power Sources, and Journal of Materials Chemistry A.

### 3.3. Author and Co-authorship

This bibliometric mapping analysis will examine authors and their affiliations to discover academic collaboration, collaborative behavior, and flow of thought [45]. Next, it will be tested using VOSviewer software. VOSviewer is defined as a software tool that enables building and visualizing bibliometric networks. VOSviewer is employed to map and visualize networks and to identify the structure of the field of study [40]. Data on collaboration can be useful for investigations and policies aimed at approaching topics with the support of specialized groups [15]. The results of bibliometric mapping using VOSviewer software produce images with a visual description of colors that are getting brighter (yellow). Larger and wider distribution illustrates more and more authors are publishing articles related to class-based storage. Furthermore, the density of images describes an alliance between one academician and another, in which authors who are grouped in high-density areas publish more research related to class-based storage in their research collaborations. Later, it can be seen in Figure 6.

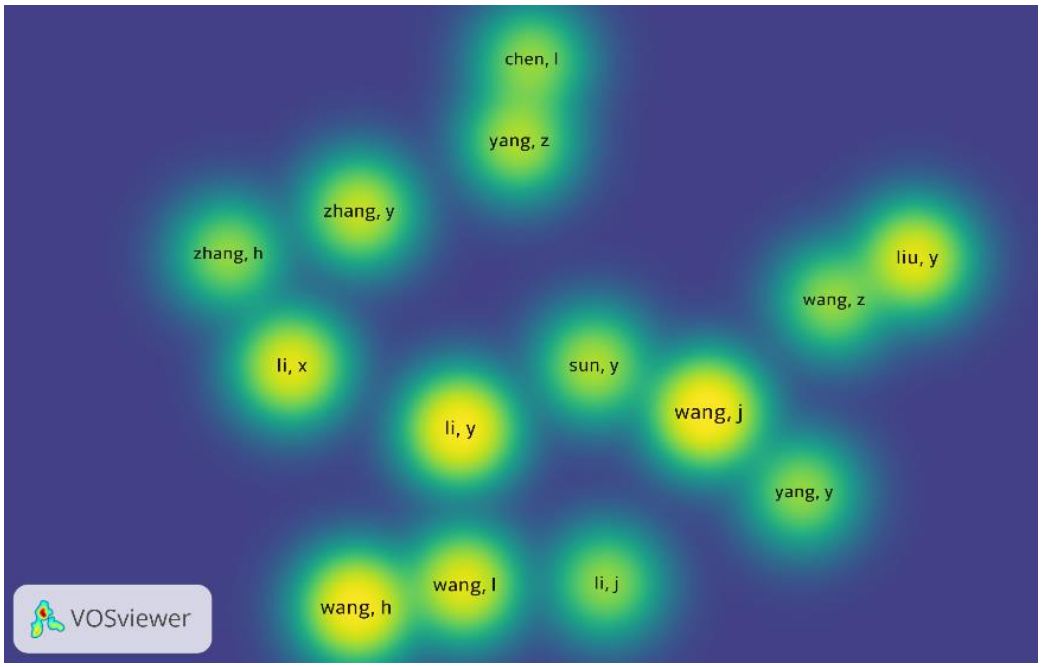


**Fig. 6. Co-authorship mapping**

The results of the analysis using the VOSviewer software based on co-authorship are used to identify which authors publish the most related articles or writings with halal class-based storage and provide important information about the patterns of collaboration of authors. [46] stated that an important feature of co-authorship network analysis is identifying the main author. Out of 980 documents, almost all the collaborating authors discuss the same topic, namely class-based storage, which is characterized by brightly colored mapping, but the density of collaboration between authors is still quite tenuous, where collaboration publishes less research related to class-based storage in their research collaboration.

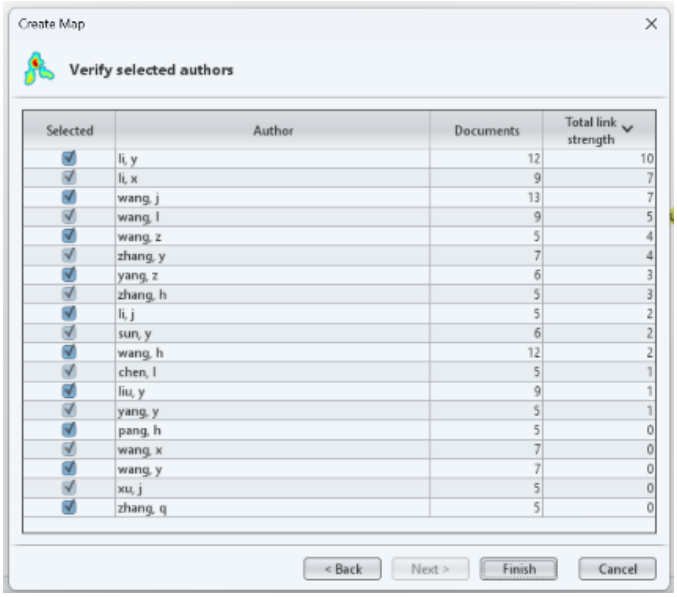


**Fig. 7. The results of the author with the most documents**

Based on Figure 7. It is identified the sequence of researchers who write the most research on class-based storage, the number of publications, and the frequency of collaborations are indicated by the total link strength. In this case, academics who have distributed a lot of research on class-based storage are Li, y with 12 publications, and 10 of them are research on class-based storage carried out in collaboration. Several academics conducted studies independently without collaboration, including Pang, h, Wang, y, who published 5 and 7 without collaboration with other academics. The co-authorship relationship will provide some information about a group of academics who are collaborating closely with the same research topic, namely class-based storage.

## 3.4. Topic-Based bibliometrics

Mapping and Clustering on bibliometric analysis using the software Vosviewer are complementary and refer to complement one another. This mapping can be used to get a detailed picture of the bibliometric network structure [47]. Trending topics-based analysis is very interesting in the world of research because it is useful for future research to help reveal inimitable and interesting topics that have never been or are rarely researched. This stage can categorize content, patterns, and trends through keyword strength.

## 3.5. Title and abstract

From the class-based storage-related title on 980 publications, 6531 keywords were found, which were divided into 85 thresholds. Then the restriction is carried out by taking 5 of the 85 thresholds so that 154 items are obtained that correspond to the 4 clusters, which dispersal is visualized in Figure 8. An explanation of the description of the keywords in the 4 clusters is illustrated in Table 2.

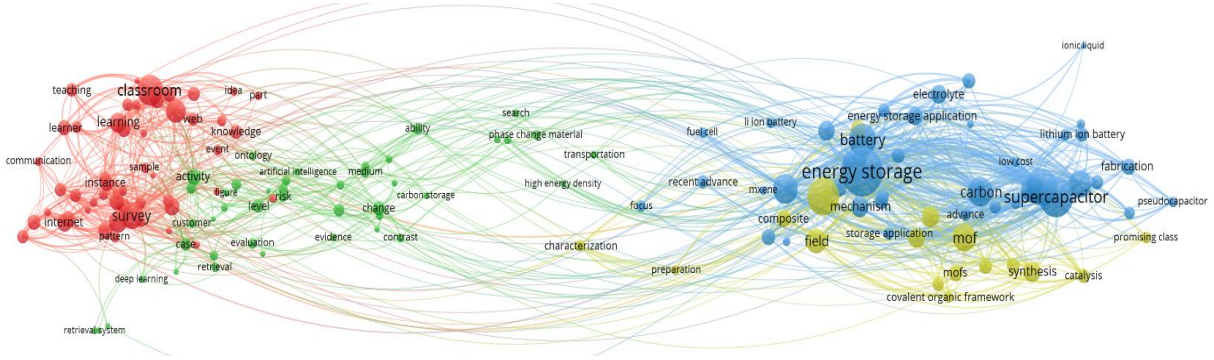


**Fig. 8. Co-Occurrence map on title and abstract**

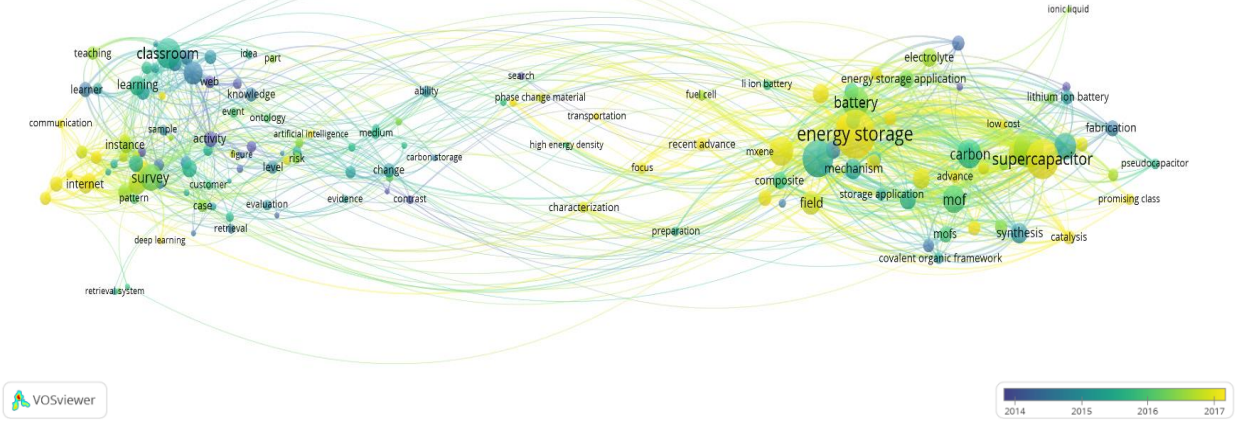


**Fig. 9. Overlay visualization on title and abstract**

The color in Figure 8 shows the clusters that are formed. Different colors indicate separate clusters: Cluster 1 is red, Cluster 2 is green, Cluster 3 is blue, and Cluster 4 is yellow. Furthermore, the larger terms in Figure 8 are contained in the titles and abstracts of publications related to class-based storage. In addition, the line shows the relationship between terms that appear together in the title and publication abstract. Moreover, the lines show the relationship among terms that exist together in the title of the publication and the abstract. The terms that often appear are "energy storage," with a frequency of 244 times, "new class," with a frequency of 151 times, and "supercapacitor," which appears 170 times.

Based on Figure 9, keyword distribution by year of publication, shown in different colors. The purple color indicates the year of publication 2014 and below, and the yellow color indicates the year of publication 2017 and above. The map shows the words “energy storage,” “promising class,” and “blockchain” published in the specified timeframes in yellow. The distribution of keywords in each cluster is shown in Table 2.

**Tab. 2. Keyword clusters**

| Cluster | Keywords |
|---|---|
| 1 | Access, algorithm, architecture, assumption, big data, big data analytics, blockchain, building, classroom, cloud, cloud computing, cloud storage, collection, communication, comparative study, covid, data storage, education, event, experience, fact, file, future, idea, instance, internet, IoT, knowledge, large number, leaner, leaning, machine, machine learning, object, organization, part, partner, person, practice, prediction, rule, sample, school, students, survey, task, teacher, teaching, thing, tool, user, web. |
| 2 | Ability, activity, artificial intelligence, assessment, carbon storage, case, case study, category, change, climate, cold storage, combination, consumer, contrast, customer, day, deep learning, difference, evaluation, evidence, figure, high energy density, influence, item, level, medium, observation, ontology, PCM, phase change material, product class, relationship, remote sensing, retrieval, retrieval system, risk, search, social class, storage policy, storage scheme, store image, term, transportation. |

| Cluster | Keywords |
|---|---|
| 3 | Advance, battery, carbon, charge storage, conversion, electrochemical energy, electrode, electrode material, electrolyte, energy, energy conversion, energy storage, energy storage application, energy storage device energy storage system, fabrication, focus, fuel cell, graphene, high performance, high performance super important class, ionic liquid, li-ion battery, lithium, lithium-ion battery, lithium storage, low cost, mechanism, mxene, nanomaterial, novel, novel class, power density, prospect, pseudocapacitor, recent advance, cent progress, sodium-ion battery, storage application storage device, supercapacitor. |
| 4 | Catalysis, characterization, composite, covalent organic farmwork, gas storage, gas storage interest, metal-organic framework, metalorganic framework, mof, mofs, new class, polymer, porous material, preparation, promising class, synthesis. |

### 3.6. Field of title

The terms mapping based on publication titles is shown in Figure 10. In this case, 12897 terms were obtained from the mapping sequence using VOSviewer. By employing five thresholds, 81 terms were attained, and for relevant terms based on VOSviewer software filtering, only 49 (60%) were revealed. The distribution of these terms is pictured in Figure 10.

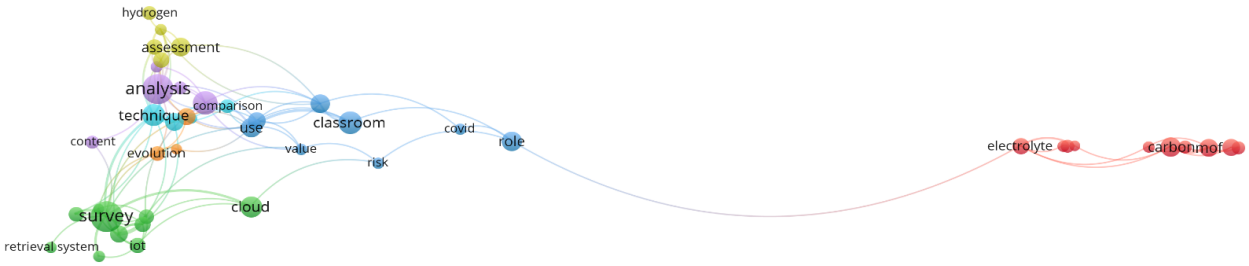


**Fig. 10. Co-Occurrence map on title**

From the results of the analysis, it is discovered that researchers use a lot of keywords included in the title of the publication under the topic of class-based storage. The keywords that appear the most are “survey” 39 times, “analyze” 38 times, “class” 24 times, and “technique” 20 times.

### 3.7. Field of abstract

The term mapping based on abstract publications is established in Figure 11. There are 42234 terms derived from the mapping using VOSviewer. By employing five thresholds, 162 terms were recorded, and for relevant terms based on VOSviewer software filtering, only 97 (60%) were revealed. The distribution of these terms is illustrated in Figure 11.

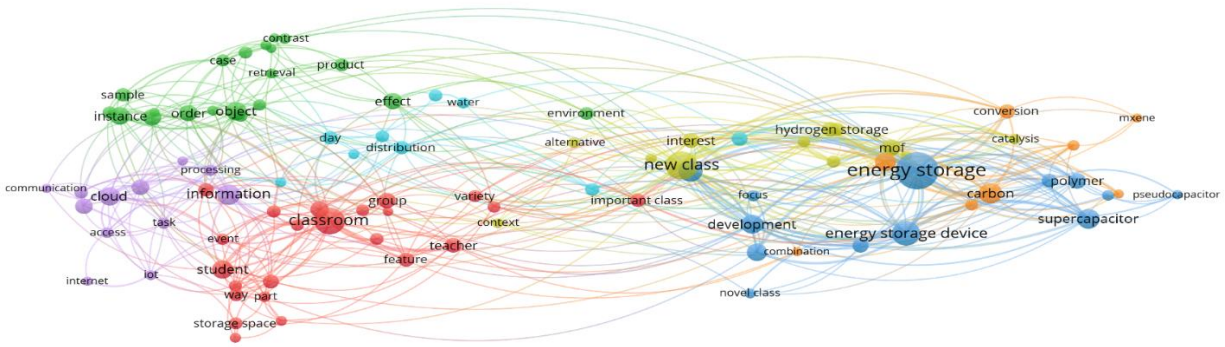


**Fig. 11. Co-Occurrence map on abstract**

The results of Figure 11 notify that researchers use a lot of keywords included in the abstract of

publications under the topic of class-based storage. The keywords that appear the most are “energy storage” 81 times, “classroom” 41 times, “new class” 47 times, “energy storage device” 36 times, “information” 25 times, and “supercapacitor” 24 times.

## 4. Conclusion

Bibliometric analysis using Harzing's Publish or Perish (PoP) software and VOSviewers analyzes the results of mapping publications with the topic of class-based storage, specifically designated to find research trend topics that have not been discussed before. In this study, 980 journals were used under the theme of "class-based storage" for further analysis. The findings came up with 144 publications out of the total articles published in 2012, which was identified as the year with the most publications in the past 10 years. The publisher that issued the most articles related to the topic of class-based storage was Elsevier, contributing 36%. The most widely published journals are the Journal of Energy Storage and the Journal of Power Sources.

The results of the study show that topic trends in class-based storage research have decreased from year to year, and there is a lack of interesting research innovations. It is expected that future researchers can carry out updates and collaboration on class-based storage topics to enhance the numbers of similar research and formulate new research topics. Sadly, research on class-based storage, with the previous number of 980 publications in the last 10 years, kept on declining year by year and hit the number of only 9 publications in 2022. Therefore, this challenge can become an opportunity for future researchers to be able to develop and innovate in each of their studies. The expected managerial implication of this research is the result of bibliometric analysis and research mapping that will be referred for warehouse’s layout arrangement and management. It is suggested that next reseach can formulate the systematic literature review towards class-based storage articles for identifying research gap analysis.

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