https://doi.org/10.31516/2410-5333.064.08[1]
УДК 004.89:02:001.891](045)

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IMPLEMENTATION OF THE INTERNET OF THINGS IN THE GLOBAL LIBRARY ENVIRONMENT: BIBLIOMETRIC ANALYSIS

The relevance of the topic. Even though the potential of IoT in optimizing library processes and creating innovative services is meaningful, we can observe a lack of research focused precisely on the implementation and application of IoT in libraries. Studying IoT in the context of libraries requires an in-depth analysis and a systematic approach to expand the opportunities for developing recommendations and guidelines for library institutions.
The purpose of the article is to analyze bibliometric data obtained from the Scopus scientometric database concerning the application of Internet of Things technologies in library and information production.
The methodology of the research includes the methods of analyzing information regarding data obtained from the Scopus database and its generalization.
Conclusions. The analysis and systematization of data from the Scopus database showed that research focuses on innovative applications of IoT, data security, and library services' development. The identified trends and dynamics of publications indicate that the role of IoT technologies in the modern library sector is persistently growing. Given the increasing number of publications from 2010 to 2022, a positive trend in the number of scientific studies in this area is expected, especially after the reduction of COVID-19 related quarantine restrictions. These conclusions can serve as a foundation for further research and the development of strategies for implementing IoT in libraries.
Scientific novelty of the paper is evident because no article containing the analysis of bibliometric data in the sphere of library industry has ever been published. These data were retrieved from the Scopus scientometric database concerning the application of the Internet of Things technologies in libraries worldwide.

Keywords: *Internet of Things, IoT, bibliometric analysis, library and information environment, library and information production, smart library, library 4.0, digitalization.*

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ВПРОВАДЖЕННЯ ІНТЕРНЕТУ РЕЧЕЙ У ГЛОБАЛЬНЕ БІБЛІОТЕЧНЕ СЕРЕДОВИЩЕ: БІБЛІОМЕТРИЧНИЙ АНАЛІЗ

Здійснено бібліометричний аналіз публікацій із тематики впровадження технологій Інтернету речей (IoT) у світове бібліотечне середовище.

Висвітлено проблематику недостатності спеціалізованих фахових наукових досліджень, у яких фокусувалася би увага саме на використанні Інтернету речей у бібліотеках. Це, власне, становить прогалину в розумінні можливостей інтеграції цих технологій у бібліотечні системи, а також викликів та перспектив, що постають у сучасному інформаційному середовищі. Для виконання детального аналізу використано дані з наукометричної бази Scopus, а визначення відповідних зв'язків між різними дослідженнями здійснено за допомогою спеціалізованого програмного забезпечення VOSviewer. Результати цієї роботи дозволяють виявити ключові теми, тенденції та напрями розвитку IoT у бібліотечному секторі. Розуміння поточного стану (і перспектив на майбутнє) використання технологій Інтернету речей у бібліотеках надає важливу основу для подальших досліджень та розробки стратегій упровадження цих інформаційних моделей у бібліотечні системи.

Ключові слова: *Інтернет речей, IoT, бібліометричний аналіз, бібліотечно-інформаційне середовище, бібліотечно-інформаційне виробництво, смарт-бібліотека, бібліотека 4.0, діджиталізація.*

Problem statement. In the modern world, where technology is rapidly developing, the Internet of Things (IoT) plays a key role in transforming various spheres of life, including the library and information sector. However, despite the significant potential of IoT to optimize library processes and create innovative services, there is a lack of research specifically focused on the implementation and use of IoT in libraries. This creates a gap in understanding how IoT can be integrated into library systems, what challenges and opportunities it can bring, and what strategies can be effective. The absence of an in-depth analysis and a systematic approach to studying IoT in the context of libraries also limits the opportunities for developing recommendations and guidelines for library institutions.

The article aims to conduct a bibliometric analysis of data obtained from the Scopus scientometric database regarding the application of Internet of Things technologies in library and information production.

State of problem development. The rapid implementation of the Internet of Things in all spheres of human activity has generated significant interest in the global scientific community, as reflected in a number of analyzed studies. Garcés-Giraldo et al. (2023) conduct a bibliometric analysis, focusing on the growing trends in IoT research, highlighting the importance of innovative technologies in the modern information space. Liang (2018) considers IoT in the context of its application in libraries, providing a literature review that elucidates various opportunities and challenges. Noh (2015) presents a model of the future Library 4.0, integrated with IoT, indicating the rapid development of technologies and their impact on library services. Rezaee et al. (2023) systematically analyze

the impact of IoT on operations management, using bibliometric and content analysis, demonstrating the deep penetration of IoT into miscellaneous aspects of management and service. Tanko et al. (2023) focus on the bibliometric analysis and metasynthesis of IoT in the context of smart buildings, extending the application of IoT beyond traditional library services. Finally, Wójcik (2016) explored the potential of IoT for libraries, emphasizing opportunities for the development of library services. These studies together form a comprehensive review of the development and implementation of Internet of Things in the library environment, opening new horizons for innovation and improvement of library services.

Presentation of the main research material. A bibliometric analysis of data obtained by means of the Scopus scientometric database on the topic of applying Internet of Things (IoT) technologies in library and information production was conducted based on the results of a formulated extended search query: "(KEY ("Internet of Things") AND KEY (library) AND NOT KEY (software) AND NOT ("Third-party") AND NOT KEY ("Programming library") AND NOT KEY ("Assembly language") AND NOT KEY ("Combinatorial library") AND NOT KEY ("Analytics libraries") AND NOT KEY (algorithms) AND NOT KEY (fog) AND NOT KEY ("Client libraries") AND NOT KEY (satellites) AND NOT KEY ("Scientific literature")) AND (DOCTYPE (ar) OR DOCTYPE (bk) OR DOCTYPE (ch) OR DOCTYPE (cp)) AND PUBYEAR < 2023". This query was designed to narrow down the search results with the following parameters: keywords — exact match for the phrase "Internet of Things" and the mandatory presence of the keyword "library", additionally introducing a filter to exclude homonymous meanings by excluding key expressions not related to the research context; types of documents included in the search results — articles, books, book chapters, or conference proceedings; publication period — from the first publication to December 31, 2022.

As a result of the query, 200 scientific works were found. The first publication in the researched field is the conference proceedings "Annals of DAAAM and Proceedings of the International DAAAM Symposium" titled "Library System Digitization Study of the Public University" dated October 20, 2010. The document is dedicated to "the implementation of RFID tags into the library and information system at Alexander Dubček Trenčín University (Slovakia)".

The statistical data obtained from the query were compiled into Table 1, which reflects the number of publications on the topic of the researched direction in chronological order.

From 2010 to 2014, there was a slow increase in the number of scientific works on the topic of the Internet of Things in Library Environment. However, in 2015, there was a noticeable decrease in the number of publications. The previous levels

were not reached in 2016 either, but starting from 2017, there was a rapid growth in the interest of researchers on the topic, reaching a peak of 37 publications in 2020. The subsequent slowdown in research in 2021–2022 can be attributed to the spread of quarantine restrictions due to the global COVID-19 pandemic, which led to limited access to many public institutions.

Table 1

Number of Publications on the topic of "Internet of Things in Library Environment" from 2010 to 2022 (according to Scopus data)

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Number of publications	2	3	3	7	11	5	6	10	20	28	37	36	32

In terms of quantitative indicators of the research results in the field of Internet of Things in Library Environment, Chinese researchers demonstrate the highest productivity, having published 63 documents, which constitutes 31.5% of the total number of works on this topic. The USA occupies the second place with 32 scientific works, accounting for 16.5% of the total volume, while Indian researchers are in the third place with 25 publications, or 12.5%. Among the most active countries in this direction, Germany (5.0%), the United Kingdom (4.5%), South Korea (4.0%), Japan (3.5%), Iran (3.0%), and Italy (2.5%) can also be pointed out, as presented in Table 2. The tenth position in the ranking is shared by several countries with an equally small number of scientific works published during the studied period.

Table 2

Top 10 Countries by Number of Publications on the topic of "Internet of Things in Library Environment"

Position	Country	Number of publications	Share of total number
1	China	63	31,5%
2	USA	33	16,5%
3	India	25	12,5%
4	Germany	10	5,0%
5	United Kingdom	9	4,5%
6	South Korea	8	4,0%
7	Japan	7	3,5%
8	Iran	6	3,0%
9	Italy	5	2,5%
10	Brazil	4	2,0%

10	Netherlands	4	2,0%
10	Netherlands	4	2,0%
10	Pakistan	4	2,0%
10	Taiwan	4	2,0%
10	Turkey	4	2,0%

Analysis of the CiteScore impact factor reveals that, as expected, the most influential journals are "Library Hi Tech" and "Lecture Notes in Computer Science", which belong to the second and third quartiles, respectively. The highest CiteScore rating at the time of the analysis belongs to "Library Hi Tech" with a score of 4.9, achieved gradually since 2017. The second place occupies "Lecture Notes in Computer Science", which reached a score of 2.2 through a slow positive trend, starting from its first publications in 2011 on the researched topic. The third position in the CiteScore ranking belongs to the publications of "Advances in Intelligent Systems and Computing", which last encountered the CiteScore calculation criteria in 2019, at that time receiving a score of 0.9. Journals like "Applied Mechanics and Material" and "Applied Mechanics And Material", which are at the lower end of the ranking, do not meet the criteria for the CiteScore calculation methodology at all. The data used for the analysis is presented in Table 3.

Table 3

CiteScore Ranking of Top 5 Publications on the Topic of "Internet of Things in Library Environment"

Pos.	Journal or publication	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	Library Hi Tech	1.6	1.8	1.9	1.9	2.1	2.3	1.8	2.1	2.3	3.2	3.9	4.9
2	Lecture Notes in Computer Science	1.3	1.4	1.5	1.5	1.5	1.6	1.6	1.6	1.9	1.8	2.1	2.2
3	Advances in Intelligent Systems and Computing	0.2	0.2	0.3	0.4	0.6	0.7	0.8	0.8	0.9			
4	Applied Mechanics and Material	Does not meet the criteria for CiteScore calculation methods											
5	Library Philosophy and Practice	Does not meet the criteria for CiteScore calculation methods											

Distribution ratio of documents by types is provided in Table 4. Analysis of the data obtained from the Scopus database reveals a dominance of conference proceedings with a total of 136 documents, accounting for 68% of the total number of scientific works. 31% of the published materials consist of 62 articles on the topic, and only 1% of the total number are 2 book chapters.

Table 4

Distribution ratio of documents by types on the topic of "Internet of Things in Library Environment" (according to Scopus data)

Pos.	Document type	Share of publications	Number of publications
1	Conference proceedings	68%	136
2	Articles	31%	62
3	Book chapters	1%	2

According to the information from the Scopus database, a systematization and classification of the sectoral distribution of publications for the established time interval was carried out, the results of which are presented in Table 5. The most active research efforts in this context are directed towards the field of computer science with 154 scientific works, accounting for 35.6%. The engineering field is noted with 99 publications, constituting 22.9%. Disciplines such as mathematics, social sciences, decision sciences, physics, and astronomy have percentage shares of 9.5%, 8.6%, 6.9%, and 5.3% of the total number of publications, respectively. Other directions of scientific activity in the context of Internet of Things in library processes have not yet demonstrated significant results.

Table 5

Distribution of Publications on the Topic of "Internet of Things in Library Environment" Relative to Scientific Fields

Pos.	Field of Knowledge	Share of Publications	Number of Publications
1	Computer Science	35,6%	154
2	Engineering	22,9%	99
3	Mathematics	9,5%	41
4	Social Sciences	8,6%	37
5	Decision Sciences	6,9%	30
6	Physics and Astronomy	5,3%	23
7	Energy	2,5%	11
8	Materials Science	2,5%	11
9	Medicine	1,6%	7
10	Arts and Humanities	1,6%	7
	Others	2,8%	12

A total of 1229 citations were recorded in the Scopus database for the period from 2010 to 2022, inclusive.

The analysis of citations from scientific works on the topic of "Internet of Things in Library Environment" for the specified time interval confirms an increasing interest of the scientific community in the application of advanced technologies in various fields. Starting from 2018, a significant and steady increase in the number of references to documents on the topic can be noted. The visualization of citation trends for the specified topic is presented in Figure 1.

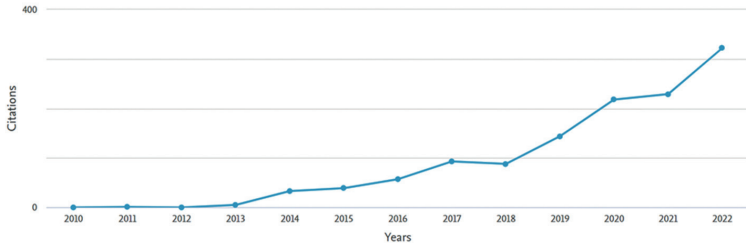

Fig. 1. Dynamics Chart of Citation Counts for the Topic of "Internet of Things in Library Environment" for the Period from 2010 to 2022

In the process of identifying the characteristics of the authorship and geographical structure of the flow of publications on the issues of applying Internet of Things (IoT) technologies in library science, it was established that from 2010 to 2022, scientists from 52 countries around the world presented their research on this topic. For deeper insight and interpretation of these data, the VOSviewer program was used, which enabled the creation of a bibliometric network map of the relationships between these countries based on the following parameters: type of analysis — co-authorship, unit of analysis - countries, considering a minimum threshold of published documents — three. The suggested selection criteria identified 19 countries that met the set parameters.

Using this tool, it was found that the highest productivity of interaction is observed between China, the USA, and the United Kingdom. However, it is important to emphasize that although China dominates in terms of the total number of publications, the scientific works of researchers from the United States have a significantly higher average number of citations per publication. This indicates the excellent quality of research provided by American scientists and their contribution to the formation of basic technological concepts on the topic under study.

Considering the overall strength of the linkages, which reflects the "Total link strength" indicator, we get the opportunity to detail the international ranking in terms of the intensity of collaboration between scientists from different countries. Table 6 presents the top ten countries in terms of the number of scientific

publications in the field of implementation and application of the Internet of Things in library science.

Table 6

Top 10 Countries by number of citations considering co-authorship interaction

Pos.	Country	Number of Publications	Number of Citations	Total Link Strength	Average Number of Citations per Publication
1	China	63	328	18	5,21
2	USA	33	705	16	21,36
3	United Kingdom	9	16	10	1,78
4	Germany	10	22	7	2,20
5	Netherlands	4	25	6	6,25
6	France	3	3	4	1,00
7	Italy	5	28	5	5,60
8	South Korea	8	41	4	5,13
9	Brazil	4	21	1	5,25
10	Pakistan	4	12	1	3,00

To analyze keyword connections in publications on the researched topic, the VOSviewer program was used. With its help, a network diagram of the relationships between them was created, based on the principle of co-occurrence, where the main unit of the analysis were all basic keywords. Out of the total number of 1945 mentioned keywords, 56 were added to the analysis, considering the threshold value of their repetition — 5 times. To increase the accuracy of the analytical study, semantic duplicates were combined, which allowed forming a list of 39 unique key phrases.

The keywords analysis is an important tool for a deep understanding of the semantics and structure of the researched topic. It allows identifying the main concepts and understanding how they correlate with each other. Studying key expressions can help to identify the main directions of research, their relevance, and also enhance the understanding of the specifics of the topic. Table 7 presents 20 most frequently used key expressions related to the topic of Internet of Things in library activity and the specifics of their interconnections. This table informs about the quantitative indicator of mentioning each collocation but also reveals the depth and nature of the relationships between them.

Table 7

Top 20 Keyword Terms in Publications on the Topic of "Internet of Things in Library Environment"

Pos.	Keywords and keyword expressions	Cases	Total Link Strength
1	internet of things	291	982
2	radio frequency identification (rfid)	59	340
3	libraries	69	247
4	digital libraries	63	214
5	library management	20	107
6	smart library	20	98
7	internet	13	69
8	university libraries	14	66
9	information management	10	56
10	management systems	8	56
11	artificial intelligence	13	55
12	automation	12	51
13	library systems	10	47
14	cryptography	9	46
15	information technology	8	43
16	computer architecture	7	34
17	data visualization	5	34
18	energy efficiency	9	34
19	cloud computing	7	33
20	energy utilization	8	32

Thanks to the algorithms of the VOSviewer program, these 39 keywords were divided into three clusters, characterizing their interconnections and thematic similarities.

The red cluster, containing 26 key phrases, primarily unites terms related to the technological foundation of implementing the Internet of Things in the library environment. Specifically, these are words that indicate automation, information flow management, the use of artificial intelligence, and specific services. Key terms of this cluster include: "internet of things", "smart library", "library services", "digital libraries", "artificial intelligence", "library management", and "information management".

The green cluster, which includes 8 key elements, focuses on aspects of information storage, its confidentiality, and energy efficiency of use. Among the most expressive terms of this cluster are: "digital storage", "data privacy", "cryptography", and "energy utilization".

The blue cluster, represented by 5 key phrases, emphasizes technologies for information visualization, principles of machine learning, and characteristics of embedded systems. Specifically, this cluster includes terms such as "embedded systems", "deep learning", and "data visualization".

Conclusions. The bibliometric analysis of publications dedicated to the implementation of the Internet of Things in the library environment revealed significant interest in this topic within the scientific community. The analysis showed that research focuses on innovative applications of IoT, data security, and the development of library services. The identified trends and dynamics of publications indicate the growing role of IoT technologies in the modern library sector. Given the increasing number of publications from 2010 to 2022, a positive trend in the number of scientific studies in this area is expected, especially after the reduction of COVID-19 related quarantine restrictions. These conclusions can serve as a foundation for further research and the development of strategies for implementing IoT in libraries.

Prospects for further research. Further research in the field of implementing Internet of Things in the library environment opens up broad opportunities for scientists and practitioners. One of the key directions is the development of innovative IoT solutions to improve the management of library resources and optimize users' interaction. Another important aspect is the study of the impact of IoT on ensuring security and confidentiality in libraries, especially in the context of storing and processing large volumes of data. Another promising direction is the analysis of IoT opportunities for creating interactive and integrated educational spaces in libraries, which will enhance their role as educational and cultural centers. Additionally, there is a necessity to investigate the impact of IoT on the accessibility and inclusiveness of library services, particularly for people with disabilities. The study of the environmental aspects of using IoT in libraries remains relevant, considering the growing attention to sustainable development and energy efficiency. Finally, an important direction is the development of methodologies for assessing the effectiveness of implementing IoT technologies in the library environment, which will necessitate understanding of their impact on library processes and users experience.

References

Garcés-Giraldo, L., Patiño-Vanegas, J., Espinosa, R., Benjumea-Arias, M., Valencia-Arias, A., & Lampen, M. C. (2023). Internet of Things — IoT research trends from a bibliometric analysis. *Journal of Information*

Systems Engineering and Management, *8*(1). https://doi.org/10.55267/iadt.07.12739. [In English].

Liang, X. (2018). Internet of Things and its applications in libraries: A literature review. *Library Hi Tech*, *38*(1), 67–77. https://doi.org/10.1108/lht-01-2018-0014. [In English].

Noh, Y. (2015). Imagining Library 4.0: Creating a Model for Future Libraries. *The Journal of Academic Librarianship*, *41*(6), 786–797. https://doi.org/10.1016/j.acalib.2015.08.020. [In English].

Rezaee, N., Zanjirchi, S. M., Jalilian, N., & Bamakan, S. M. H. (2023). Internet of things empowering Operations Management; A systematic review based on bibliometric and content analysis. *Telematics and Informatics Reports*, 100096. https://doi.org/10.1016/j.teler.2023.100096. [In English].

Scopus preview - Scopus - Welcome to Scopus. (n.d.). *Www.scopus.com*. https://www.scopus.com/search/form.uri?display=advanced. [In English].

Tanko, B. L., Essah, E. A., Elijah, O., Zakka, W. P., & Klufallah, M. (2023). Bibliometric analysis, scientometrics and metasynthesis of Internet of Things (IoT) in smart buildings. *Built Environment Project and Asset Management*. https://doi.org/10.1108/bepam-11-2022-0179. [In English].

VOSviewer - Features - Highlights. (n.d.). *VOSviewer*. https://www.vosviewer.com/features/highlights. [In English].

Wójcik, M. (2016). Internet of Things — potential for libraries. *Library Hi Tech*, *34*(2), 404–420. https://doi.org/10.1108/lht-10-2015-0100. [In English].

Надійшла до редколегії 19.10.2023