Research Article

Internet of Things - IoT research trends from a bibliometric analysis

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ARTICLE INFO	ABSTRACT
	This bibliometric study aims to analyze the scientific literature on information systems and IoT using the Scopus database, which has the largest number of indexed journals, through quantity, quality, and structure bibliometric indicators, to identify the most relevant research actors. Papers were selected that had information systems and IoT in their title. The analyses were performed in Rstusio, VosViewer and Excel. The results are classified by authors, journals, countries of publication, and keywords. With the aim of identifying research trends in the subject. Among the main findings, it is a topic of interest due to the growth in the last few years. The collaborative works are reflected among countries such as the United States, China, United Kingdom, and authors from the same countries dispersing the publications in important journals of Information technologies, such as the IEEE. Additionally, the main topics are related to reducing risks in information systems, logistics systems, health, smart cities, real-time information, and decision making. Keywords: IoT, Information systems, Industry 4.0, Digital Transformation, Bibliometrics, Trends

INTRODUCTION

Information systems are one of the organizations' most significant areas of study worldwide (Hernández Trasobares, 2003). Its functions aim to collect, store, process, transmit and produce quantifiable data (Li, 2022). Therefore, understanding its nature and approaches to IoT through a bibliometric discipline provides relevant statistical data to establish the level of scientific growth of the subject (Lopez, 1972; Pritchard, 1969).

According to Pritchard (1969), bibliometrics is a subdiscipline of scientometrics that uses mathematical and statistical methods to analyze the course of written communication or literature of a scientific nature, as well as the authors who produce it. Similarly, Bornmann (2005) indicates that the mathematical and statistical methods used in this discipline make it possible to analyze the impact caused by a scientific study. On the other hand, their use is supported by the important role of publications in disseminating new knowledge to achieve concrete explanations, relate them to science and determine the growth of any scientific area (Durieux et al., 2010; Katz, 1999).

This article aims to show the results of a bibliometric analysis of information systems and IoT as a technology that has become relevant in recent years. According to Li (2022), the IoT is changing first of all the course of people's lives by offering

comfort to their daily lives and also to companies at an alarming rate, given its high level of impact by allowing them to save production time and facilitating the collection of information in real-time.

THEORETICAL CONTEXTUALIZATION

The term "Internet of Things" (IoT) was initially coined in 1999 by the Englishman Kevin Ashton, who proposed a technology in which a variety of objects in the physical world could establish a connection to the Internet through sensing devices (Thoutam, 2021).

The Internet of Things (IoT) allows the interconnection of objects to facilitate constant communication to any place, person, or time (Khan et al., 2021). Gauray et al. (2022) mention that the connection between objects is through a network, whose main function is exchanging data with the central storage. Youness (2022) also explains that the main characteristic of such data is their quantity, i.e., they are massive data in real-time, usually between different entities at high speed. As Georgios et al. (2019) explain in their study of IoT in the context of Industry 4.0, Industry 4.0 aims to transform traditional industries into smart ones by incorporating innovative technologies, and one such technology is IoT. IoT seeks to permeate the everyday environment and its objects, linking the physical world with the digital world and allowing people and "things" to be connected anytime, anywhere, with anything and anyone.

The fields of application are varied, the most representative being the health sector, construction, logistics, surveillance, agriculture, and smart city (Youness, 2022). As Youness (2022) states, there is a combination between IoT and other technologies, such as Cloud Computation, Smart Grid, and Smart Building, where the fusion of these technologies allows for tracking large amounts of information.

Information systems work together with IoT; it is a crucial component since it facilitates the procurement of resources and the selection of available services (Forestiero & Papuzzo, 2021). For example, this relationship can be observed in the logistics sector because they impact product traceability systems, visual management systems of the logistics process, and intelligent supply chain of companies, among others (Zhang, 2021). Technology such as IoT and information systems are also relevant to the construction field. In a research conducted by Lei and Zhang (2021), the authors study the concept of a smart city based on cloud computing and IoT.

METHODOLOGY

An exploratory study was carried out employing the bibliometric technique, using Scopus as a source of information. This database is recognized worldwide for its trajectory in the scientific field, compiling information on the main areas of knowledge and integrating more than eighteen thousand publications and five thousand publishers (*Arias-Ciro, 2020*). Additionally, it has more than forty million records related to publications, web pages, conferences, and patents

(Velandia Pachero & Escobar Castillo, 2018). The search terms (IoT and Information systems) are initially established to structure the following search equation.

(TITLE ("Information systems") AND TITLE ("Internet of things" OR iot)).

General aspects of the records obtained are described in **Table 1.** Subsequently, the bibliometric indicators of quality, quantity, and structure were defined, which, as Camps (2008) states, make it possible to highlight the scientific activity, its rigor, and the influence (or impact) of both the research and the sources.

Table 1. General aspects. Source: Own elaboration based on Scopus

General aspects	Quantity
Records	166
Authors	437
Keywords	461
References	4001
Conference paper	90
Articles	58

The information was analyzed and processed through the Microsoft Excel® office automation tool, which, according to Teng et al. (2019), is an ideal technological tool for data analysis. There, the data were organized, and the respective figures were generated. As a second software, Vosviewer was used to create a visualization map of cooccurrence (keywords), where the size of the rectangle indicates the relationship with the total number of articles, and the color is the cluster grouping. Twenty-nine keywords were selected, each with a minimum occurrence of 6 times.

RESULTS

Figure 1 contains information on the scientific production of information systems and IoT. The variables involved are the number of publications and years. In global terms, the figure shows the behavior of publications per year in a period of 14 years (2009-2022) in which highs and lows have been experienced, being the year 2021 with the highest production with 23 articles; which represents 14% of the total for the period. Among the topics addressed this year, the fourth industrial revolution and its application stand out, as mentioned by Zhang and Hao (2021), who propose a development in the safety management of construction workers based on the Internet of Things. On the other hand, Pereira and Muñoz (2021) established an information system for medical records with integrated access via the Internet of Things.

In 2020, 21 publications can be seen, representing 8.18% of the period's total, having as main topics related to intelligent information systems and cybersecurity. This is consistent with the findings of Savukynas (2020) in his article about information system security for identification and authentication of smart

devices, where the author discusses the vulnerability of the data that are daily processed between devices, how to reduce this risk and, detect more easily the existing anomalies at the level of the information system of the equipment related to IoT.
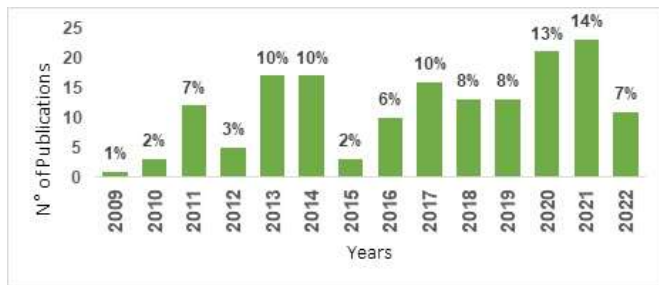

Figure 1. Publications per year.
Source: Own elaboration based on Scopus

Based on the above, it is evident that this is a growing subject that contributes to developing the world's information systems. In this regard, it can be identified that the countries where the largest number of publications is concentrated are: In first place is China, with 77 publications, representing 43% of the total. Their approaches are varied, but topics such as smart cities and cloud computing are representative. Lei and Zhang (2021) propose the construction of a smart city, its characteristics, applicability, and its integration with IoT. In the educational field, there are also contributions, such as the study by Hong (2021), where he proposes an information and educational system that increases student performance and accessibility to educational resources at the computer level.

In second place is India, with 18 publications, representing 14% of the total. This country's main topics are machine learning and business management. Gaurav et al. (2022) contributed to mitigating the effects of computer viruses that affect the functionality of enterprise systems.

Figure 2 shows the ten authors with the most publications in information systems and the Internet of Things, whose latest studies have addressed issues related to information logistics management (Wei, 2014) and IoT-based information systems (Zhang, 2012). Concerning these authors from China, it should be noted that Wei Y, despite having five publications, is not a current author since his research was between 2011 and 2014. On the contrary, the author Zhang Lin has been present on the subject from 2011 to 2020. Afterward, Luo J (the author who stands out in this indicator since the first publication on the subject was made by him, and after years of absenteeism, he made a new contribution in 2022), Sun Qingfeng and Kong Fansen each with three publications, from China, their thematic interest is in remote monitoring information systems (Luo et al., 2009) and information systems for emergencies (Sun et al., 2012).

Then we have Din, Zarina; Jambari, Dian Indrayani; Yahaya, Jamaiah Haji, and Yusof, Maryati Mohd from Malaysia with three publications each, who study security management with the internet of things (Din et al., 2021) and finally Strobel (2020) with three publications, is interested in

scientific production related to the integration of IoT in health systems, to increase efficiency and profitability while alleviating the increasingly heavy burden of health systems worldwide.
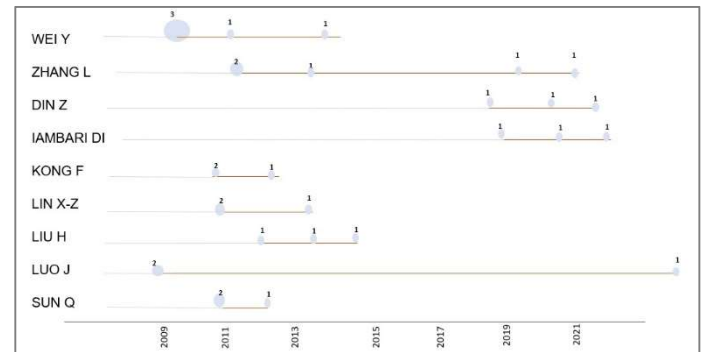

Figure 2. Authors' production over time.
Source: Own elaboration based on Bibliometrix

Figure 3 shows the indicator of the most cited authors about information systems and IoT. The author Cheng Xie has 457 associated citations in the first place. The article with the highest impact, entitled Ubiquitous data access method in IoT-based information system for emergency medical services, proposes creating a data model for further storage and interpretation (Cheng et al., 2014). Authors Hu Jingyuan, Bu Fenglin, Xu Li Da, Cai Hongming, and Xu Boyi have 421 citations. On the other hand, Hu Jingyuan et al. (2014) propose research on the integration of information systems and medical records, where the author wants to make a contribution to improve access to information by treating physicians to give more appropriate diagnoses in less amount of time. On the other hand, Bu Fenglin et al. (2017) investigate issues related to processing mining for mobile information systems, where they highlight the importance of properly managing the connection between large-scale data and business processes with IoT. Xu and Li (2021) focus their research on highlighting the relevance of the topic, challenges, and trends.
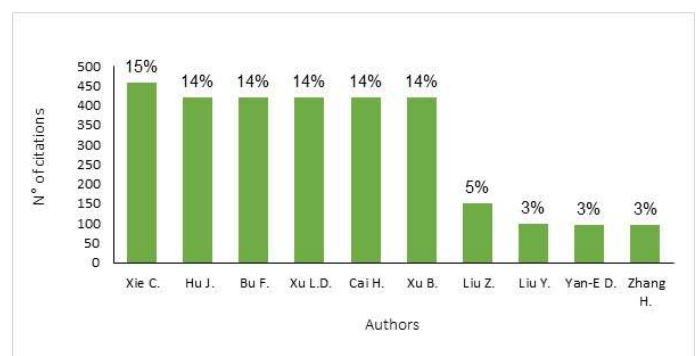

Figure 3. Top 10 Most cited authors.
Source: Own elaboration based on Scopus

The indicator of a number of publications per journal shows the journals with the highest productivity and published articles related to IoT, as shown in **Figure 4**. The left column shows the countries where the publications are from, the journals in the middle column, and the related keywords in the left column.
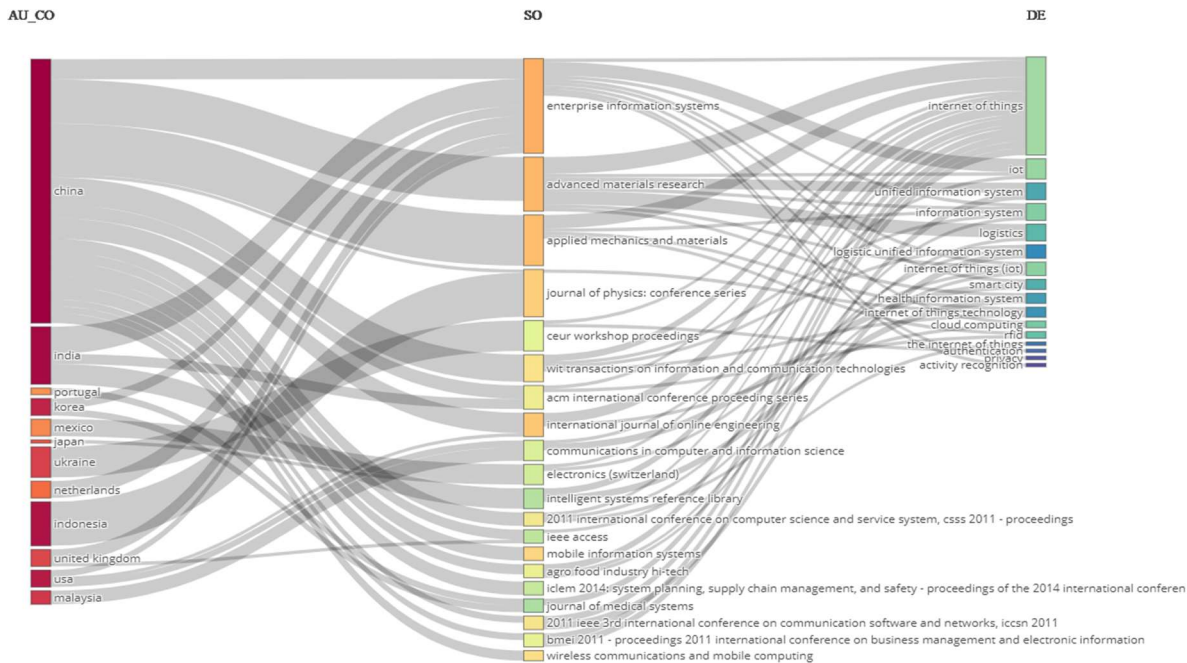
Figure 4. Highest productivity journals.
Source: Own elaboration based on Bibliometrix]

In first place is Enterprise Information Systems with ten publications in total. This is a UK journal whose main topic of interest is decision science, which can be evidenced in studies such as the use of integrated information systems in supply chain management, in which they wanted to test in an empirical way the effects of the application and use of integrated information systems in companies (Gallego González et al., 2012) also cloud computing (Cloud Computing) and smart city (Smart City).

As shown in the **Figure 4**, this journal publishes articles from different countries, mostly from India and China, followed by Advanced Material Research, a German journal with seven publications, all from China, which investigates topics related to engineering and technology, a study related to the subject is the Analysis of the development mode of the application of the Internet of things, in this research seeks to analyze and expose how IoT is applied from an operational point of view (Wen et al., 2013). Additionally, other significant topics are logistics and unified information systems. The remaining eight journals have between 5 to 2 publications, and their main topics of interest are Engineering, computer applications, and computer networks, among others.

In the case of this indicator, Pareto's law is not fulfilled since 72% of the journals published 80% of the articles. Additionally, the percentage was separated by quartiles. It was found that 9% of the journals publish 25% of the scientific articles, 30% of the journals publish 50% of the scientific articles, 66% of the journals publish 75% of the scientific articles, and 72% of the journals publish 80% of the articles. This means that knowledge on the subject is distributed in a small number of journals, so there may be large knowledge gaps.

Figure 5 shows the journals with the highest impact determined by the number of citations. Among the top 10, the IEEE Transactions On industrial is identified as the journal

with the highest impact, with 421 citations. Its focus is on computational intelligence, electronics, and industrial applications, among others. An example is an article entitled Pharmaceutical Cold Chain Management (Mihai et al., 2018), where a model is proposed to ensure access to data from the entire drug chain, from the time it leaves the laboratory until it reaches distribution centers such as drugstores. Second place is the Conference on Intelligent Computing Technology and Automation, with 96 related citations. The topics discussed at that conference were artificial intelligence and computational science. The research above by Yan (2011) was part of the conference, and the relation and relevance with the exposed topic are observed.

Finally, the journal Information systems Frontiers is in third place with 90 related citations. This journal is from the Netherlands, and its most representative research topics are related to information systems, software, and computer and communication networks (Sequeiros et al., 2011; Li et al., 2022; Li et al., 2014).
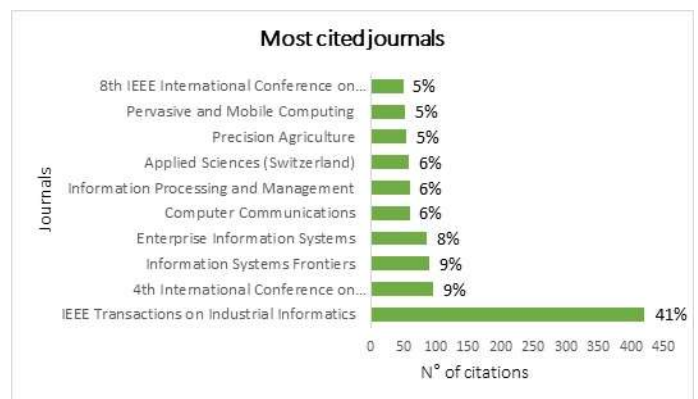

Figure 5. Most cited journals.
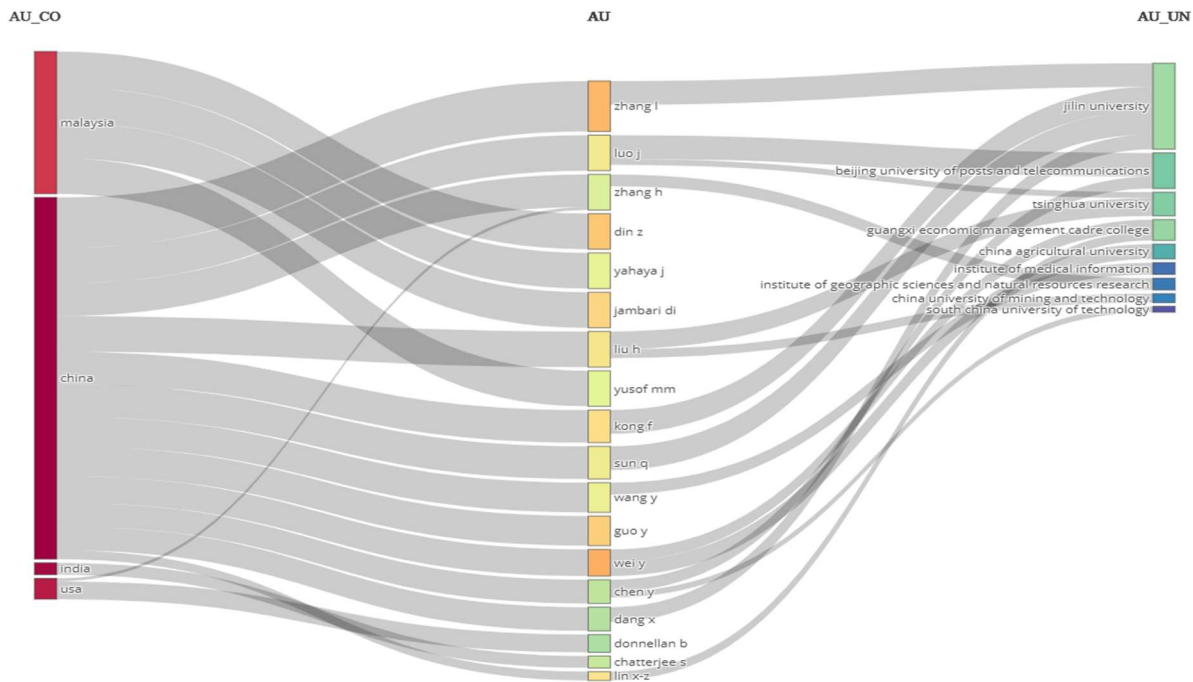Source: Own elaboration based on Scopus

Figure 6. List of authors with countries and affiliation. Source: Own elaboration based on Bibliometrix
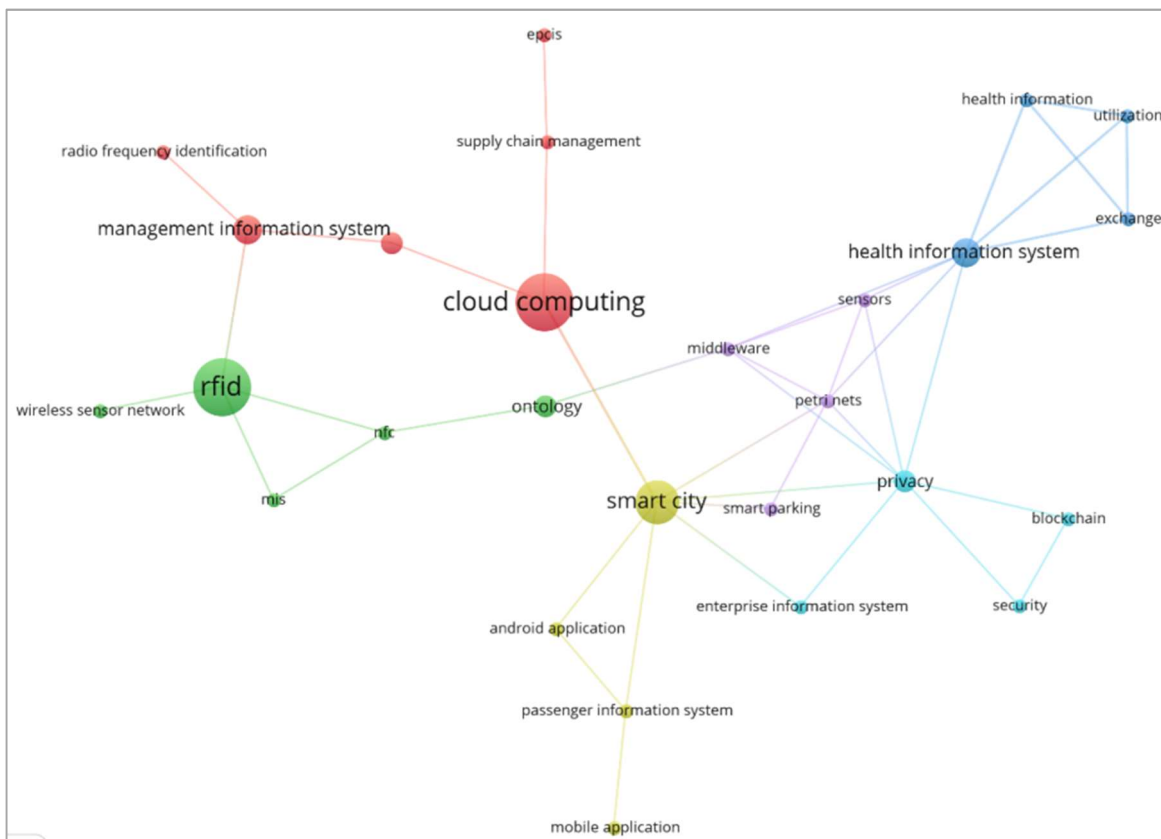

Figure 7. Keywords.
Source: Own elaboration based on VosViewer

Figure 6 shows the most productive authors with their respective countries and the institutions they belong to. The left column shows the countries, in the center the most productive authors, and in the right column the institutions to which these authors belong. As representative data, it is evident that the three most productive authors are from China, followed by Malaysia, with four authors in the top 10. With respect to affiliation, it is evident that Jilin University has the most authors researching information systems and IoT.

Figure 7 shows the keyword network between IoT and information systems, resulting in 3 clusters. The words information use, decision making, medical information systems, health information system, health care, hospitals, Rfid (radio frequency identification), and management system information are related to the red cluster. There it can be observed that they have an affinity with the articulation of the health sector and information systems. An example of this is the research conducted by authors Guoqiang et al. (2016), where they propose an intelligent medical information system with the aim of decreasing waiting times and increasing the efficiency of hospital management.

For the green cluster, words such as smart city, cloud computing, distributed computer systems, information services, and information management are related, denoting the interest in studying these topics, as evidenced by Raki et al. (2022), whose approach given by defining the relationship between IoT, cloud computing and M2M. Additionally, Xiaoguang (2022) proposes optimizing the enterprise financial information system by integrating IoT, information systems, and smart cities.

The blue cluster, composed of the application programming interface, telecommunication network, real-time, computer systems programming, and radio frequency identification, is mostly focused on programming applications, such as an information system as a Python service (Anca et al., 2016), real-time applied to parking guidance with the internet of things (Liao & Wang, 2014) and finally object-oriented radio frequency (Tamotsu, 2017).

CONCLUSIONS

According to the results found, research approaches in recent years address how to propose solutions that mitigate the vulnerability of the data that are daily transacted between devices, how to reduce this risk and how to more easily detect existing anomalies at the equipment's information system level.

Given their nature of handling large volumes of information, information systems have quite significant risks, so an evaluation of security management for adopting IoT technology must be constantly carried out. These topics mark the current research trends in the field of information systems and IoT.

In bibliometric results, quantity is not synonymous with quality since the authors who publish the most do not coincide with those who have the greatest impact in terms of citations. Therefore it is suggested to expand the number of researches on the subject so that knowledge is not in a small number of authors.

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