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THE RESEARCH ON LITTLE’S LAW IN SCOPUS INDEXED JOURNALS: A BIBLIOMETRIC ANALYSIS

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ABSTRACT
This study aims to determine the development map of research in the field of Little’s Law using bibliometric analysis. The study was conducted in July 2022 by conducting a search through the Scopus database with the keywords little’s law or little law. The search data is then analyzed descriptively based on the year of publication, the subject area, the name of the institution and country that publishes it, the name of the journal/publication, the collaboration of the researcher, and hot spot research. To get a map of research developments, the data is exported from Scopus. The export data are then processed and analyzed using the VOSviewer application program to determine the bibliometric map of research developments in the field of little’s law. The results showed that the number of publications on the results of research in the field of little’s law in Scopus in 1867-2022 had experienced fluctuation and the subject area with the most published in computer science. The country and institution that contributes the most publications to research results in little’s law indexed in Scopus are The United States and Yanshan University. Furthermore, The majority of productive authors are independent researchers. Network visualization shows that the hot spot of research developments in the field of little’s law is divided into 4 clusters with a total of 27 topics.

KEY WORDS
Little’s law, bibliometric analysis, VOSviewer, systematic mapping, Scopus, research gaps.

The application of operations research (OR) techniques into production systems are considered to be increasingly widespread with the advent of the Second World War and continue to be applied today (Potter et al., 2020). One of the tautologies that have been transferred by Little's Law (John D. C. Little, 1961), states that L = W, L is the number of items in the queuing system, is the average item arrival rate and W is the average time spent in the system. In addition to Little's Law analysis which focuses on the values of each station in the production process, there is also an analysis of the shape of the distribution, examining whether the L and W distributions are related. Significant work in this area has been carried out by Haji & Newell (1971) as well as by Bertsimas & Nakazato (1995) although, as Little (2011) notes, the conditions for the distributional form of Little's Law applied are limiting.

Little's Law is one of the basic laws in queuing literature (Kim & Whitt, 2013). It has been widely used in managerial decision-making in areas such as inventory management, process improvement, capacity planning, and manufacturing and service operations (e.g. Klassen & Menor, 2007; Rust, 2008; Khojasteh-Ghamari & Sato, 2011). The queuing system consists of discrete objects (i.e. items) that arrive at the system. These items could be cars in traffic on the highway or at toll booths, people queuing at the supermarket, computer instructions waiting to be executed, or products on the Little (2011) production line.

Little's law is logically understandable, it was used in surgery research for years before being proven by Dr John Little in 1961. Little’s law is particularly evident for steady-state queuing systems. However, this assumption may not hold in many queuing systems in the real world. The law was later extended to other queuing conditions (Little, 2011). One of the extensions is related to the condition of the queuing system being empty at times 0 and T. One example is a department store where the number of customers is zero at the beginning and end of the day (J. Little & Graves, 2008). Little’s law applies to this queuing system, and we can find the average queue length and number of people in the store at any time by having the average time customers spend in the queue or the store in total and (Little, 2011)'s average arrival rate. Another extension is the condition in which the queue starts with a non-zero number of items at the beginning and end of the period T and the queue does not end at the specified time. One well-known example used by scholars is the wine cellar (J. Little & Graves, 2008; Wolff, 2011). Bottles are the items in this example, and the number of bottles in the dungeon at any time is the number of items in the system. Little’s law also holds for this condition, and the average time of bottles in the cellar over some time T can be calculated using this law. Another example is an inventory system where the quantity of goods is usually greater than zero to avoid product shortages and dissatisfaction among customers.

Hopp & Spearman (2008) provide several uses for using Little's Law including calculating queue lengths, measuring and reducing cycle times, managing inventory levels and evaluating backlogs. The relationships described by Little's Law provide the foundation for the approaches used in the pursuit of effective process flow by companies (Afy-Shararah & Rich, 2018) and concepts such as Lean Thinking (Womack & Jones, 1996) and fast and even flow (Schmenner & Swink, 1998). Little's Law is a basic law in management with significant implications in areas such as lead time management, inventory management, and manufacturing operations and services (Hendijani, 2021). It was also previously stated by Little (2011) that Little's law applies to all queuing systems for services and manufacturing.

The flexible use of Little's law in various fields makes research on the use of Little's law also cover different fields such as little's law analysis in the food and service industry (Sakamoto, 2019; Kostami & Ward, 2009), property industry (Bashford et al., 2005), the telecommunications industry (Miao & Chen, 2013), the machinery and electrical manufacturing (Morita et al., 2015; Lödding & Piontek, 2018; Antunes et al., 2018; Hendijani, 2021) and the textile industry (Perona et al., 2016). Therefore, Little's Law remains relevant for today's operations management practitioners and scholars, with examples in journal papers (Lödding & Piontek, 2018), academic books (Holweg et al., 2018), practitioners' books (Modig & Åhlstrom., 2012; Pound et al., 2014), blogs (Mulholland, 2017), and university teaching (Dobson & Shumsky, 2006; Lapre, 2010).

The amount of little's law analytical literature has forced researchers to investigate current research trends on the topic. In the rapidly developing information age, efficiently analyzing rapidly developing scientific documents in research areas is an important and essential task for researchers (Su et al., 2021). Traditional literature analysis is to qualitatively summarize several literature by the researchers themselves. This method is strongly influenced by the level of the researcher and is easy to cause large deviations in results, strong subjectivity in recommendations, and other problems (Ding et al. 2017). While quantitative bibliometric analysis can analyze titles, keywords, word frequency, citation information, authors, collaborators, publishers, dates, and other literature information using computer software, the results obtained include research status, research institutions, and research hotspots (Zhou et al., 2021). This method can process many documents from many angles of analysis simultaneously, and the analysis results have high reliability and can be visualized (Zong et al. 2012). So far, there are few literature-based studies in the field of the little's law method, one of which is from Potter et al (2020) and in particular with bibliometrics analysis have not been found.

Today, common bibliometric analysis software includes VOSviewer, Cite space, Hist cite, etc. Among them The VOSviewer is especially used when working with small and large datasets; it displays data maps and various analytical analyses (Kokol et al., 2018; Llanos-Herrera & Merigo, 2019; Md Khudzari et al., 2018; Shah et al., 2020). Van Eck & Waltman (2013) also stated that VOSviewer provides additional mapping methods based on scientific principles to create useful maps, networks and data. Compared with other software, the visualization effect of VOSviewer is better, and the operation is relatively simple. In this work, the researcher uses a special bibliometric visualization tool to analyze little's law articles taken from the Scopus database to explore research trends. The main objective of this paper is to reveal mainstream research trends, current focus, and future directions of little's law studies around the world.

METHODS OF RESEARCH

This study uses the Scopus data source because it indexes the best journals with the latest articles (Aghaei Chadegani et al., 2013). In addition, Scopus is the largest database of abstracts and citations that provides more accurate data (Fiorenzo Franceschini et al., 2016) and handles 1.4 billion citations and 16 million author profiles. This study is designed to determine research trends about little's law analysis. The search used the keywords “little’s law” or “little law” along with its dimensions and was conducted for articles, abstracts, and keywords. For this purpose, data were collected on 26 July 2022 using the Elsevier Scopus database. Preliminary results in the first step revealed 290 articles; the oldest article on little's law was published in 1867. In the second step, the type of article was narrowed down to articles in the form of journals, and conference proceedings and had the English language so 264 articles were found. In the third step, the articles that have been collected will be subjected to a systematic electronic identifier (EID) check and one duplicate article is found which is finally deleted. Therefore, a total of 263 articles were used in the final data analysis.

The academic literature has proposed various approaches to examine the effect of certain variables, such as scientometrics, bibliometrics, altemetrics, informetrics, webometrics, librametrics, patentometrics, and article-level metrics (Das, 2015). Bibliometric data analysis helps researchers to conduct comprehensive investigations of a variable from various angles and highlight its development path (Fellnhofer, 2019). Therefore, this study uses bibliometric analysis to determine the significance of the little's law analysis method in academic research. This analytical technique offers several ways to understand the variable under investigation: (1) develop our understanding of a particular area of research by providing insight into the field of research, the behaviour of variables and their regularities; (2) reveal the latest trends about the variables; and (3) provides variable relationships and networks.

The 263 articles were exported to VOSviewer, a software tool for constructing and visualizing bibliometric webs. The VOSviewer is especially used when working with small and large datasets; it displays data maps and various analytical analyses (Kokol et al., 2018; Llanos-Herrera & Merigo, 2019; Md Khudzari et al., 2018; Shah et al., 2020). Similarly, Van Eck & Waltman (2013) stated VOSviewer provides additional mapping methods based on scientific principles for creating useful maps, networks and data. Thus, all of the maps combining the respective linkage groups that were created using the VOSviewer include items. In this research, to analyze the overall characteristics of the enhanced literature, these documents were imported into the "VOSviewer" software (version: 1.6.17) and carried out data statistics and mapping of literature information including keywords, authors, institutions, journals and countries.

During the data import process, because the analysis type is set to "co-authorship", "author", "organizations", and "country", in the unit of analysis column, is selected; because the analysis type is set to “co-occurrence”, “all keywords” in the unit of analysis column are selected; Other data analyzes of the combination were not used in this study. In the graphic visualization derived from "VOSviewer", "co-occurrence keywords" are an important way of revealing the main content in the research area. The higher the frequency of occurrence, the more research results, and the more spots are reflected in this area (Gao et al. 2018). For entries such as “research country”, “research author”, “research institution”, and “research journal” in other graphic files in the text, a larger circle indicates that the entry is a hot topic; the closer the circle to the centres indicates the more important the entry is; the closer the circle indicates the closer relationship between the two; and the thicker the line connecting the circles indicates the more often they appear in the document at the same time. circles with different colours represent different clustering groups (Gao et al., 2018). For charts with a time axis, proximity to the blue area indicates that time is earlier, as a pioneer or early pioneer; getting closer to yellow indicates a more recent time, and it is an active or new direction emerging in the research field (Jin et al., 2019).

RESULTS AND DISCUSSION

Between 1867 and 2022, 263 research articles on little's law were published (Figure 1). Among these 263 publications, only 69 articles are available with open access. The oldest publication dates back to 1867, and there were no other publications until 1951. These articles began to experience an increasing number of articles after 1979. One of the main reasons for the gap in the early period was probably the Second World War which affected almost every area of the world. The world includes research. By the end of the twentieth century, a steady increase in publications had appeared in the academic literature. The most publications of articles occurred in 2012 with a total of 19 articles in one year. The huge increase in publications was due to the increase in higher education institutions (Chen et al., 2009) and collaboration, the rise of research culture in some countries (such as India) as well as the overall increase in publications worldwide (Nature, 2018; Researchtrends, 2019). From these statistics, it can be assumed that the number of publications is still experiencing instability but has never again touched less than 5 articles.

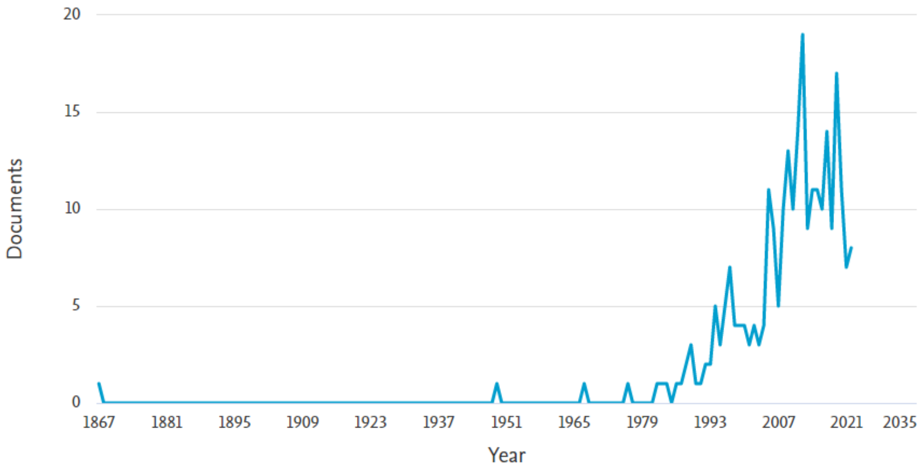

Figure 1 – Little's law article publication trend (Source: Scopus 2022)

The use of little's law analysis affects various industries and also various fields of research studies, as mentioned in Table 1. The field of study using little's law is not only related to operational management but also, to computer, environmental science, engineering and others. The Scopus database has categorized these 263 articles into 19 subject areas. Table 1 presents the top 10 fields of study in little's law research. In little's law research, computer science, mathematics and engineering were the highest, while business, management, and finance had the second highest number. It is often assumed that the use of little's law is related to corporate management and business, but our analysis shows that management and business are sixth. Although there are substantial differences between fields of study (F. Franceschini & Maisano, 2014), it should be recognized that journals are sometimes categorized in more than one field. For example, the Journal of Managerial Operations is categorized into four areas: business, management, and accounting; decision science; Thus, it was found that articles published in interdisciplinary journals, categorized in more than one field, had more coverage and citations than articles published in journals categorized in only one field.

According to the results of the analysis obtained by VOSviewer, 263 articles were taken about the analysis of minor law studies from 41 countries. Table 2 lists the 10 most productive countries which accounted for 63.11% of the total publications with 166 articles. The United States has the largest number of articles published in the field of minor law, with 120 documents and 1899 citations. China ranks second with 27 documents and 1176 citations, while Japan ranks third with 19 documents and 209 citations. Ranked between 4th and 10th place, the remaining 7 countries accounted for 59 publications and 648 citations.

Table 1 – Subject Area of Little's Law Article

Subject	The number of Documents
Computer Science	127
Mathematics	97
Engineering	91
Decision Sciences	73
Social Sciences	35
Business, Management and Accounting	32
Medicine	15
Economics, Econometrics and Finance	7
Art and Humanities	6
Environmental Science	5

Source: Scopus, 2022.

Table 2 – Country Productivity Trends

Country	The Number of Documents	Citation
The United States	120	1899
China	27	176
Japan	19	209
Canada	15	78
Taiwan	10	133
Germany	7	103
England	7	239
Australian	7	29
India	7	18
France	6	48

Source: VOSviewer, 2022.

The United States and China have taken the dominant places in the little's law study. To further analyze country co-authorship for the little's law article document, a visual network map created by VOSviewer for cross-country collaboration is shown in Fig. 2, where 22 countries issuing more than or equal to 3 documents are involved. In the map, the influence of a country in the field of research is reflected by the size of the node, while the closeness of cooperation between different countries is indicated by the thickness of the link. Following the statistical data in Table 2, the 3 countries with the highest collaboration (US, China, and Japan) developed the most collaboration. Furthermore, as shown in Figure 2, the United States still dominates in cooperating with other countries, while other countries in collaborating with only 1 or 2 countries.

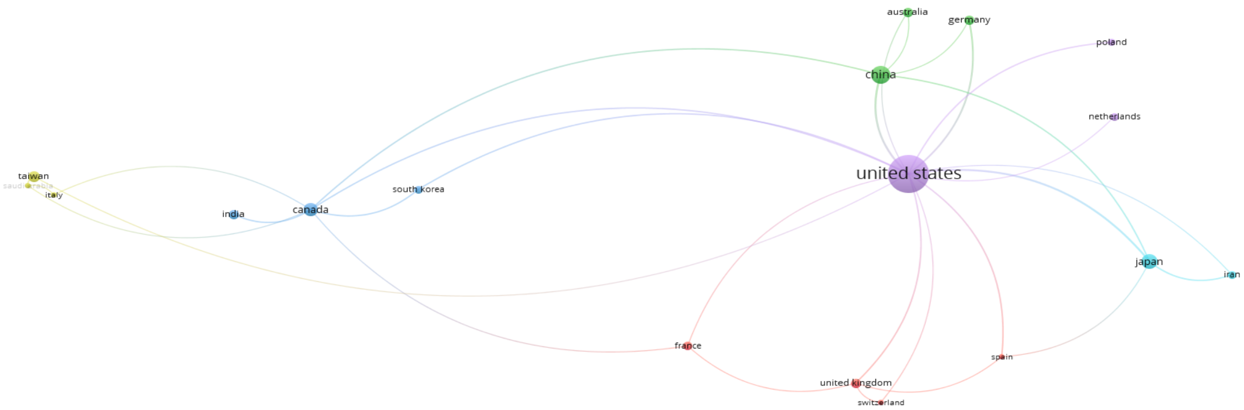

Figure 2 – Distribution of Main Countries in Little's Law research (Source: VOSviewer, 2022)

In addition to analyzing the distribution of countries, the research also analyzes the institutions or organizations of researchers in the little's law study. Among the articles taken, there were 405 organizations involved, and Table 3 lists the 10 institutions that contributed the most. The number of publications from these 10 institutions has a relatively even distribution. However, little's law papers published with the affiliated agency Laboratories

General Telephone & Electronics Corporation have significantly more citations (126) than other agencies, although GTE has published only 2 articles in this area, indicating that papers from this organization are more influential. Statistical results also show that 5 of the top 10 organizations are from the US, indicating that the US has the most significant impact on little's law research.

Table 3 – Institution Productivity Trends

Organization	The Number of Documents	Citation
Yanshan University	7	94
Tsinghua University	4	23
University of Kuala Lumpur	4	8
Bell Laboratories	3	57
University of Wisconsin	2	57
Universiti Kebangsaan Malaysia	2	4
GTE Laboratories Incorporated	2	126
Colombia University	2	12
University of Steyr	2	15
Henan Polytechnic University	2	0

Source: VOSviewer, 2022.

Figure 3 shows the collaboration between research institutions in little's law. Each node represents an institution, while the links symbolize collaboration. Node size and link thickness were positively correlated with the organization's publication number and collaboration closeness, respectively. In Figure 3, the minimum number of documents for an institution is set as 3. Therefore, 11 institutions meet the threshold. However, based on the results of the analysis using the VOSviewer, shows that these research institutions have not been linked or have never conducted collaborative research in the field of little's law analysis.

Figure 3 – Distribution network of research organizations in the field of Little's Law
(Source: VOSviewer, 2022)

Various 185 journals published 263 selected articles, with an average of 1.42 articles per journal. Of the 185 journals, 151 (81.62%) published only one article, 19 (10.27%) published two, and 15 (8.1%) journals published the same and more than 3 articles. Table 4 lists the most productive journals for publication of little's law study articles, and the journals are sorted by the number of documents. Queueing systems have the highest number of documents, namely 17 documents with the second largest citation (303), while the journal with the most citations is obtained by operations research with 321 citations with the second largest number of documents, namely 8 documents. The third to fifth have a similar number of documents, namely the European Journal of Operation research with 6 documents and citations of 73, the Journal of Applied Probability with 5 documents and 37 citations, and the international journal of Production research with 4 documents published and citations of 26. The core journals that publish papers on little's law research are multidisciplinary or interdisciplinary science journals in economics, civil engineering, Management, mathematics, and other disciplines.

Table 4 – Ten Most Productive Journal Sources for Little’s Law Research

Journal	The Number of Documents	Citation
Queueing Systems	17	303
Operation Research	8	321
European Journal of Operation Research	6	73
Journal of Applied Probability	5	37
International Journal of Production Research	4	26
Performance Evaluation	4	38
Production and Planning Control	4	27
International Journal of Production Economic	3	46
Journal of Construction Engineering and Management	3	63
Journal of the Operational Research Society	3	12

Source: VOSviewer, 2022.

Co-authorship analysis can help individual researchers seek collaboration opportunities and provide information about research networks and schools of theory and thought. Based on the data we collected, 469 authors contributed to the 263 articles retrieved. In this case, 401 authors wrote only one article, 43 authors wrote only two articles, and 25 authors wrote three or more. Performance VOS performs co-authoring analysis by creating a map of the researcher's network (Fig. 4). In the picture. 4, both the minimum number of publications and citations from an author were adjusted to 3. Then, 25 authors met the threshold. Similarly, each node represents an author, and node size is positively correlated with the number of publications. The cooperative closeness between the authors is reflected by the link. According to the results of the VOSviewer analysis, in little's law research, the majority of productive authors are independent researchers, and the scale of co-authorship cooperation is small and limited.

Co-occurrence can include keywords that are similar to each other and based on the same topic but not the same. In bibliometrics, the co-occurrence of the author's keyword is used to reveal the research points of the discipline. This study uses VOSviewer to generate a network of co-occurrence keywords related to little's law, as shown in Fig. 5. Here, the minimum number of keywords that appear is set to 7. Of the 2003 keywords retrieved, 27 keywords met the threshold. It can be seen from Figure 5 that the 27 keywords form 4 clusters (differentiated by yellow, blue, red, and green colours) to identify research hotspots, according to the default clustering method in VOSviewer. Table 5 lists the keywords and their frequency of occurrence in each cluster.

Table 5 – Co-occurrence of author keywords

Cluster 1 (Merah)	Cluster 2 (Hijau)	Cluster 3 (Biru)	Cluster 4 (Kuning)
Little's law (89)	Mathematical model (20)	Queueing theory (66)	Operation research (18)
Scheduling (19)	Computer Simulation (19)	Queueing networks (25)	Throughput (18)
Production control (14)	Markov process (17)	Sales (9)	Stochastic systems (10)
Inventory control (13)	Performance evaluation (12)	Queueing system (8)	Operations management (7)
Process control (10)	Simulation (11)	Waiting time (8)	Manufacture (8)
Optimization (8)	Quality of service (10)		
Cycle time (7)	Computer network (8)		
Inventory (7)			
Work in process (7)			
Cycle time (7)			

Source: VOSviewer, 2022.

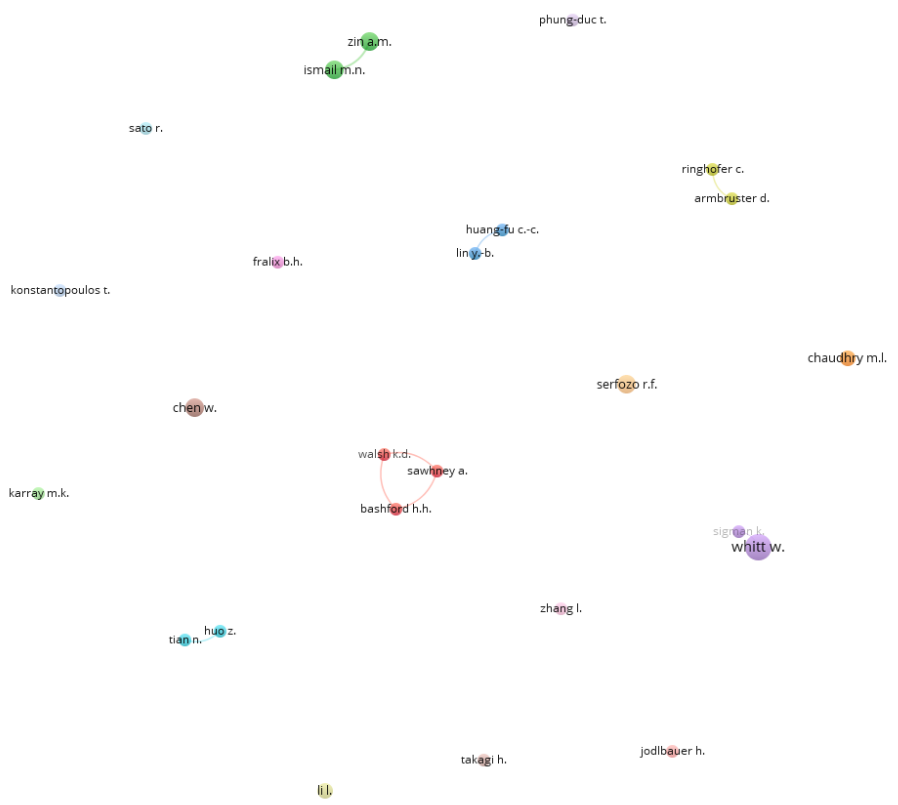

Figure 4 – Distribution of authors' networks in little's law penelitian research (Source: VOSviewer, 2022)

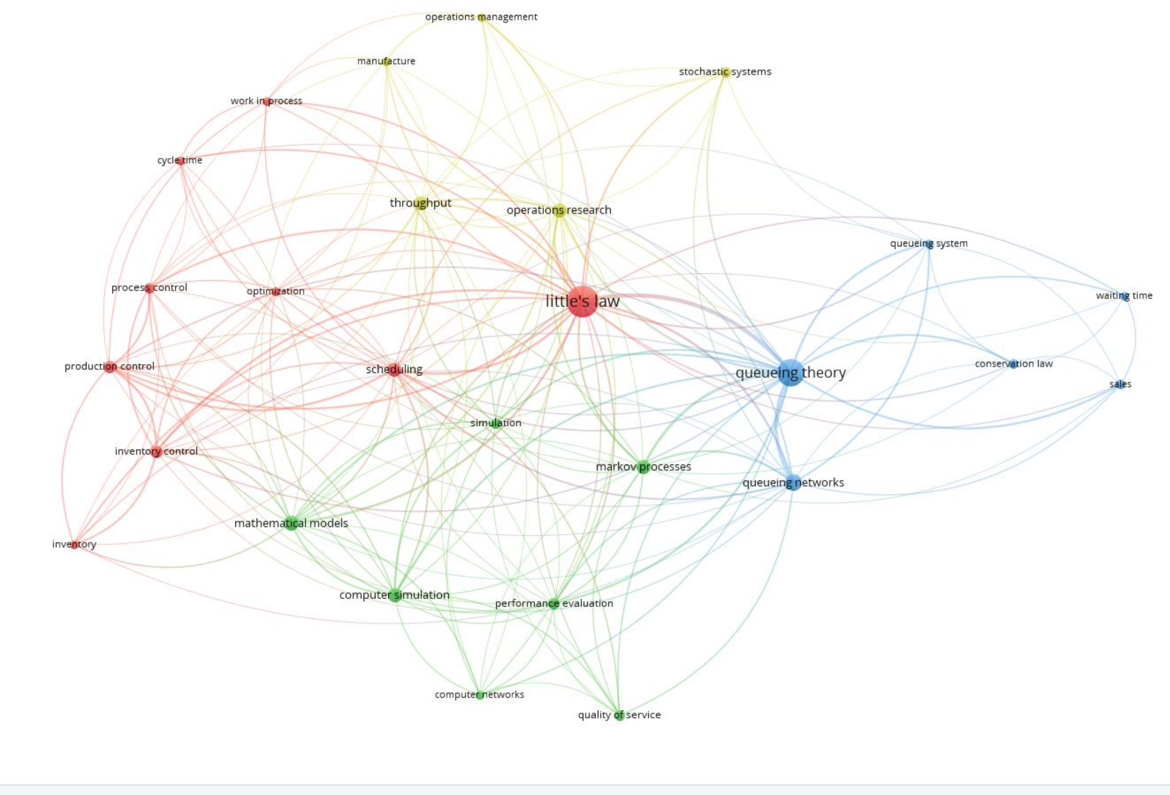

Figure 5 – Co-occurrence network of keywords in Little's Law (Source: VOSviewer, 2022)

Cluster 1

The keywords in cluster 1 follow the subject word little's law, which reflects the research domain of the little's law study. The top 3 keywords in this cluster apart from little's law are scheduling, production control and inventory control, with occurrences of 19, 14 and 13 respectively. These keywords are related to production processes and supply chain, little's law is used to predict work processes based on process cycle times and items in the process flow and these predictions are compared with the facts that occur in the field, the relationship described by Little's Law provides the basis for the approach used in pursuing an effective production process flow by the company (Afy-Shararah & Rich, 2018). In addition, the supply chain strategy with little's law in mind is designed to suggest a set of basic managerial supply chain management focuses with which companies must make constant and continuous improvement efforts, regardless of product characteristics that have been designed and implemented by the competitive situation (Morita et al., 2015).

Cluster 2

The top 3 keywords in this cluster are mathematical model, computer simulation and Markov process, with occurrence frequencies of 20,19 and 17 respectively. The tautological nature of Little's law from a mathematical perspective makes it applicable to many situations ('applications') and many uses ('utility'), evidenced by various industrial applications and various definitions of variables. The ability to relate the three performance measures ('simplicity') is also mentioned in (Hopp, 2008). The simplicity with which this can happen and therefore can be understood by management is perhaps best seen in the example of computer rebuilds (Guide et al., 2005). While the relationship between little's law and computer simulation is expressed by (J. D. C Little, 2011) namely little's law for computer architecture in a web service environment to reduce response times. In his approach, the focus is on multicore CPUs and memory, and how they can be best designed to serve high-volume web traffic. Little's Law applies to the processing of large-scale computational jobs with highly variable job content, i.e. processing wait times, along with work in progress and throughput rates. In the use of little's law to achieve the Markov process, an example is a research on the analysis of the arrival queue of update batches with fault-tolerant servers using the shift operator method (Yu & Tang, 2022) and generalized little's law and its application to discrete-time G/D/1 queues. with correlated arrivals (Miao & Chen, 2013).

Cluster 3

The top 2 keywords in this cluster are queuing theory and network or what can be called queuing, with a frequency of 66 and 25 occurrences. Little's Law is a basic law in management with significant implications in areas such as waiting for time management, inventory management, and manufacturing operations. and services (Hendijani, 2021). This was also previously stated by Little (2011), Little's law applies to all queuing systems for services and manufacturing. Hopp and Spearman (2008) provide several uses for using Little's Law including calculating queue lengths, measuring and reducing cycle times, managing inventory levels and evaluating backlogs. Queuing becomes a dimension related to little's law because in its mathematical form it is presented by John D. C. Little (1961), which states L = W, L is the number of items in the queuing system, is the average item arrival rate and W is the average time. spent in the system. Little's Law is one of the fundamental laws in queuing theory which has practical implications in various fields of management (Chhajed & Lowe, 2008). The law relates the waiting time to the average queue length (i.e. the average number of items in the queue) through the average arrival rate to the system. The queuing system is the embodiment of the stock-flow mechanism in the managerial system. In a stock-flow system, the flow rate resembles the arrival rate in Little's Law and stock accumulation resembles the average queue length. Little's Law is often used in predicting the performance of various dynamic systems such as manufacturing and inventory management (Gerst, 2004) and queuing systems (eg (Andalib et al., 2018; Do et al., 2018; Ghaffarzadegan & Larson, 2018; Sankaranarayanan et al., 2012).

Cluster 4

The top 2 keywords in this cluster are operations research and throughput, with the same frequency of occurrence, namely 18. The application of operations research (OR) techniques into production systems are considered to have become more widespread with the advent of the Second World War and continue to this day. One of the tautologies that have been transferred is John D. C. Little's Law (1961). What factors contribute to Little's Law's versatility in operations management? The first question considers empirical transferability, which can be defined as the ability to be applied in a variety of different empirical settings and reflects sentiment (Micklethwait & Wooldridge, 1996) when considering good management theory. These questions are answered through a systematic review of the literature, providing a structure with which to test flexibility between different research studies. The second question refers to the qualitative analysis derived from the relevant research paper sketches. Versatility relates to the ability to adapt to different situations, and therefore having this attribute allows Little's Law to successfully transfer between empirical settings. Next to throughput, Little's law ties the required throughput rate to the cycle time at each stage. They recommend that the cycle times used in each calculation be based on historical data; alternatively estimated from the theoretical time multiplied by the appropriate factor for the individual process type as determined from the manufacturer's records. The throughput rate is related to customer demand and allows for factors such as current yield loss. Combining these throughput rates and cycle times through Little's Law allows work-in-progress goals to be set for each process (Potter et al., 2020).

CONCLUSION

In this paper, the researcher presents a visualized bibliometric analysis of research trends in little's law analysis and its use. This paper is composed of a series of science maps from the number of annual publications, countries, institutions, journals and authors and by conducting a keyword co-occurrence analysis to obtain the research hotspots of the little's law analysis discussed. The main conclusions are as follows:

(1) The results of this study can provide resources for researchers who are working on little's law analysis studies, fostering collaboration between authors from different countries. The extracted high-frequency keywords help searchers identify hotspots and understand research dynamics and directions.

(2) The increase and decrease that still occurs every year in little's law analytical studies show that it is a research discipline that is still active and needs more exploration to find new things. According to the research distribution analysis, the United States and China have taken the most prominent role in the little's law analysis study. In particular, the US is the most productive country. Publications in studies using little's law were evenly distributed among research institutions, but publications from queuing systems and operations research received significantly more citations than other institutions. Concerning source journals.

(3) Through the analysis of co-occurrence of keywords and grouping discussions, the researcher found that the research points of the little's law analysis study focused on the production process and supply chain. In addition, the use of little's law in the discussion of mathematical models and computer simulations is also high.

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