Mapping the Landscape: A Bibliometric Analysis of Staff Scheduling Optimization Research Trends and Keywords Evolution

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ABSTRACT

This bibliometric analysis aims to investigate research trends and the evolution of keywords in the field of staff scheduling optimization. The data will be retrieved from the Scopus database, and the publications in articles written in English between 1989-2023 will be examined. The results will be presented in visual analysis using Microsoft Excel and VOSviewer. Initially, 1351 articles were retrieved from 1971 to 2023. However, only 673 met the requirements and proceeded to identify the research trends in terms of leading countries, prominent authors and journals. Besides that, this study also aims to determine the popular keywords and how the keywords evolved based on the chronological groups: Initial phase (1989-1999), Development phase (2000-2011), and Exploration phase (2012-2023). The results show that the United States is the most productive country, contributing 20.57% of all publications, with Jonathan F Bard as the most prominent author. The most productive journal for staff scheduling optimization was the European Journal of Operation Research, with 40 articles and 1962 total citations. Meanwhile, the keyword co-occurrences have evolved significantly, from 20 keywords to 3889 keywords over 34 years. These findings provide valuable insight for future researchers in identifying the research gaps in top journals, authors, and publishers. Hence, it will help in designing future research strategies and collaborations.

Keywords: Staff scheduling optimization, Scopus, trends, keyword evolution, VOSviewer

INTRODUCTION

The workforce is the most critical resource in any organization and business. If the company can control and utilize the workforce wisely, it can help the company to provide a happy working environment and achieve its targeted goals. Therefore, how the company effectively utilizes workforce resources is often a must in planning [1]. As in planning, the company always wants to find an operational efficiency method that can maximize productivity while minimizing cost, and one of the methods is staff scheduling. Staff scheduling is essential in various sectors such as healthcare, manufacturing, plantations and services. This optimization focuses on the efficient allocation of workforce resources that will meet organizational needs while minimizing cost and maximizing productivity [2], [3], [4].

The complexity of staff scheduling arises from the requirement to balance multiple constraints, such as employee skills, shift preferences, workload variations, and other regulatory constraints [5]. These included ensuring that staff allocation followed labour laws and contractual agreements, adequate coverage for

fluctuating demand, and minimizing overtime and idle time for each worker, which is based on a company's limitations [6]. According to [1], staff scheduling problems can be categorized into three main categories: shift scheduling, leave scheduling and tour scheduling. Shift scheduling focuses on assigning non-overlapping shifts, and leave scheduling focuses on planning a weekly schedule by including the day off in the schedule. In contrast, tour scheduling assigns both shifts and days off in the schedule. Over the past decades, there has been a lot of research on staff scheduling, with various approaches and algorithms proposed to solve personnel scheduling problems in several sectors. Therefore, this paper will discuss the research trends in the previous studies of staff scheduling optimization through bibliometric analysis.

Bibliometric analysis is one of the review methods that provides a systematic and quantitative evaluation of the impact and development of specific research areas through publication trends, citation patterns, authorship, keywords used and collaborations [7], [8]. This technique involves the systematic collection and analysis of bibliographic data to determine and reveal patterns, relationships, and gaps in the existing literature [9], [10], [11]. By applying this approach to staff scheduling optimization, this study will help future researchers identify the current research trends and influential literature in this field by highlighting the evolution of research themes in previous studies. Thus, this paper will combine the bibliometric review method with data visualization tools such as VOSviewer and Microsoft Excel to portray the landscape of staff scheduling optimization research. At the end of this study, the following questions are aimed to be answered: (RQ1) What are the research trends in staff scheduling optimization, and which influential articles, authors, and journals have the most significant contributions to this field of studies? (RQ2) What are the popular research themes in staff scheduling optimization, and how did these themes evolve in the previous research?

METHODOLOGY

This study will retrieve the bibliographic data from the Scopus database on June 30, 2024, with the query string used to search the selected topic, as in Figure 1. The Scopus database is used in this study because it is one of the largest databases that allow researchers to conduct literature reviews on various aspects [12]. Instead of Scopus, the data can also be retrieved through Publish or Perish software, which was developed by Anne-Will Harzing [13]. However, there is a limitation on the total number of documents to be retrieved, which is up to 1000 only [14]. Meanwhile, Scopus can retrieve more than that.

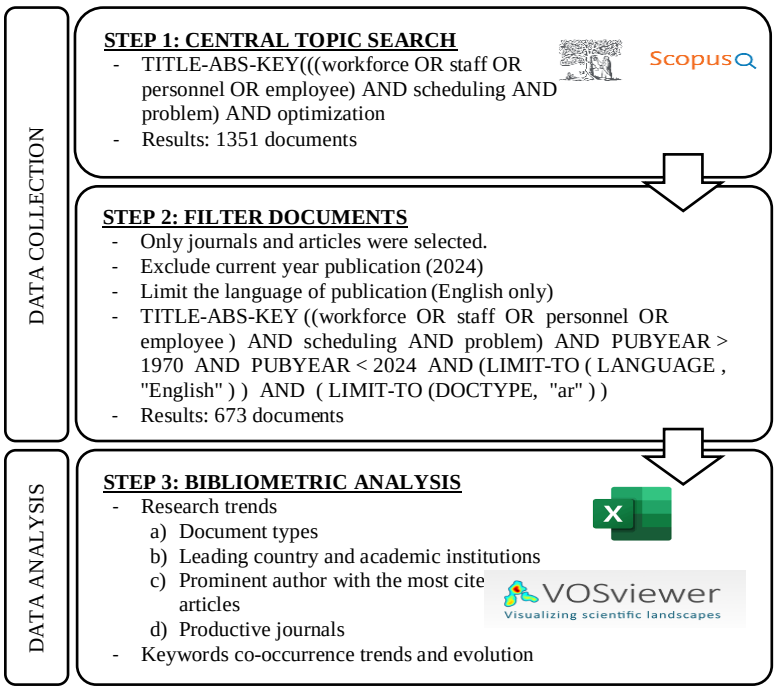

Figure 1. Bibliometric analysis flowchart

The data retrieved by using the topic search query, as in Figure 1, will then proceed to pass through filter steps, which consist of several criteria that need to be followed, such as type of documents, year of publication, and language used. Then, the remaining number of documents will analyzed to determine the research trends in the leading countries, the prominent authors and journals that actively published articles related to staff scheduling optimization and the popular keywords used in the previous research. In order to determine the research gaps from the bibliometric analysis, this paper also discussed the research theme evolution based on the chronological groups (Initial Phase: 1989-1999; Development Phase: 2000-2011; and Exploration Phase: 2012-2023). So that future researchers can understand the growth of staff scheduling optimization research and propose new topics or algorithms.

Initially, 1351 documents related to staff scheduling optimization were detected in the Scopus database, covering from 1971 to 2024. However, only 673 articles are the final data that met the requirements of document type (article) and language (English) and were published up to the year 2023, as suggested by [14] and [15]. These data will then be exported into CSV format for further bibliometric analysis to identify the research trends of staff scheduling optimization.

This paper will use a few analytical methods to analyze and visualize the findings. The VOSviewer software will be used to perform the country co-authorship analysis and keyword co-occurrence analysis and illustrate the results in the network visualization to show the connection between each document, author or country in the data [15], [16]. The stronger the correlation between two nodes, the higher the link strength is given [15]. According to [17], two counting options can be chosen: full counting and fractional counting. However, in this paper, full counting will be selected in all analyses using VOSviewer since it will give a link strength between nodes in an integer value, which is determined based on the co-authored documents [16]. Besides VOSviewer, Microsoft Excel and Publish or Perish software will be used to calculate the data metrics and graphs.

RESULTS AND DISCUSSION

This section will have three sub-sections, which explain the research trend, keyword occurrences evolution based on chronological groups and the research gaps for future research.

A. Research Trends and Impacts

The research trends and impacts for staff scheduling optimization research will be discussed in terms of publication trends, geographical distribution and influential articles.

1. Publication trends

Based on the online data retrieved from the Scopus database on June 30, 2024, it can be seen the number of publications on the topic of staff scheduling optimization has shown significant growth, especially in the last decade. This scenario reflects the increasing interest and advancements in this field of study. Initially, 1361 documents detected that “shift scheduling optimization” was used in the abstract, document title, or keywords. According to Table 1, it can be seen that the most popular publication type for this research area is in article form, with 761 documents, which contributes to 56.33%. Meanwhile, 500 and 53 documents are in the form of conference papers and reviews, respectively. However, in the further analysis of research trends, only the documents in article form will proceed as suggested by [15].

After the elimination phase, only articles written in English and published up to the year 2023 were selected. As a result, only 673 articles will then be classified based on chronological groups (1989-1999; 2000-2011; 2012-2023), as shown in Table 2 below. It can clearly be seen that research on the topic of staff scheduling

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optimization has demonstrated substantial growth over the years. The initial stage, from 1898 to 1999, witnessed a modest output of 56 articles (8.32%) of 637 articles. Meanwhile, in the development stage, spanning from 2000 to 2011, there was a significant increase with 119 articles (17.68%), bringing the cumulative publications to 175. This value kept increasing during the exploration stage, which is the most prolific period from 2012 to 2023, and it produced 498 articles, which contributed to 74% of the total articles. This publication data trend highlights a growing interest in this topic, and a lot of new sectors and algorithms have been explored.

Table 1: Document types of "staff scheduling optimization" publication.

Document Types	Number of documents	Contribution Percentage % (N=1351)
Article	761	56.33
Conference Paper	500	7.01
Conference Review	53	3.92
Book Chapter	18	1.33
Review	14	1.04
Book	3	0.22
Note	1	0.07
Retracted	1	0.07

Table 2: Number of publications based on chronological groups.

Duration	No of publications	Cumulative publications	Percentage % (N=673)
Initial Stage: 1989 to 1999	56	56	8.32
Development Stage: 2000 to 2011	119	175	17.68
Exploration Stage: 2012 to 2023	498	673	74.00

2. Geographical Distribution

The geographical distribution of the staff scheduling optimization research is evidence of the worldwide interest in this study area as well as the collaborative efforts. This subsection will examine the contributions from various countries, focusing on the leading countries that have the most articles published in the Scopus database. Microsoft Excel will be employed to illustrate the top countries in this study based on the number of publications. In contrast, VOSviewer will be employed to analyze and demonstrate the collaboration in network maps. When using VOSviewer, the analysis of country co-authorship is set to be full counting with a maximum 25 number of countries in a single document, and only the countries with five or more articles will be considered for further analysis and network map visualization.

As a result, there were 77 countries that published staff scheduling optimization from 1989 to 2023, with the United States (131 articles) being the most productive country. The United States has started publishing articles about staff scheduling optimization since 1989, with the highest being in 2019 (12 articles), which resulting a contribution of 20.57% to this field of study. It is followed by China (117 articles), the United Kingdom (43 articles) and Canada with 117 articles, 43 articles and 41 articles, respectively. Among these countries, China, which is the second leading country, is the only country with a late publication, which started in 2007. China has actively published on this topic in the last decade, with a range of 12 to 23 articles yearly. However, Malaysia ranks 27th with only eight articles that started their publication in staff scheduling optimization in 2013, with two articles by [18], [19]. The details of the geographical distribution

per year for the top 10 countries are shown in Figure 2.

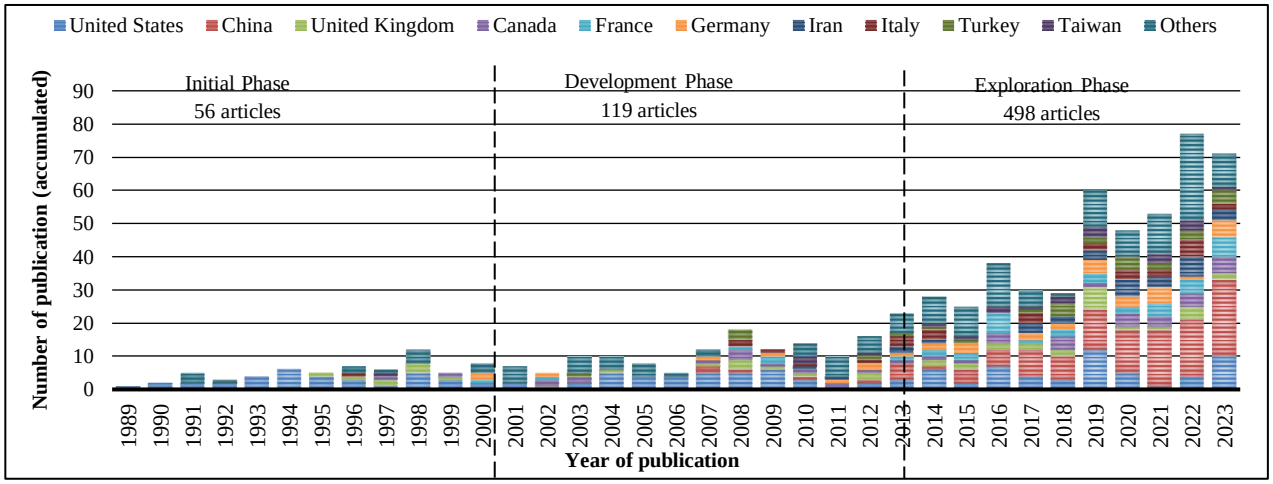

Figure 2: Staff scheduling optimization publications trends among the leading countries from 1989-2023.

Besides highlighting the leading countries, this paper also discusses international collaboration in the research of staff scheduling optimization research. Many research projects are the result of global collaboration. The joint initiative finance by international organizations also contributed to the diversity and depth of research output. These international collaborations among 77 countries in staff scheduling optimization research can be analyzed using VOSviewer and demonstrated in a network map, as shown in Figure 3. As a result of the analysis, only 37 countries met the threshold (maximum 25 countries per document and minimum five documents per country). These 37 countries consist of 3 from North America, two from South America, 16 from Europe, 13 from Asia, two from Oceania and one from Africa. These countries are then clustered into five clusters based on the collaboration frequency, as shown in Figure 3 below. Countries that collaborate often tend to have similar co-authorship patterns [20].

As can be seen from the network map in Figure 3, it consists of circles and lines, which indicate the number of publications and collaborative efforts, respectively. The larger the size of the node, the more publications have been published, while the shorter the distance between nodes (country), the stronger the connection. Each node will have a link strength value, which represents the weightage of the number of co-authored articles against the total number of authors [15], [16]. The details about each node (country) with the link strength (number of collaborations) can be clustered into five clusters, as in Table 3.

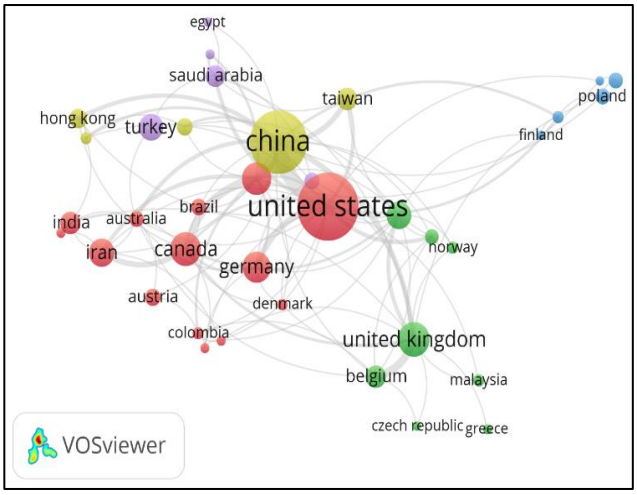

Figure 3: Network visualization map of international collaboration on staff scheduling optimization research from 1981 to 2023. (Online map: https://tinyurl.com/2ksw9o7x)

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As in Figure 3, there are five clusters of country co-authorship analysis: Cluster 1 (Red) had 14 items, Cluster 2 (Green) had eight items, while Cluster 3 (Blue), Cluster 4 (Yellow) and Cluster 5 (Purple) had five items each which clustered using Louvain algorithm for modularity optimization [21], [22]. This algorithm aims to identify strong community structures within the network. As a result, the strongest link among all countries was the United States, which has 46 link strengths. This data shows that the United States had 46 international collaborations out of 131 articles. It was followed by China (44 link strength) and the United Kingdom (26 link strength). Meanwhile, Malaysia, which ranks 27th with eight articles, only collaborated in two countries: the United States and the United Kingdom. Therefore, international academic collaboration in staff scheduling optimization research in Malaysia remains crucial.

Table 3: Geographical Distribution of Staff Scheduling Optimization Research by Clusters

Cluster	**Country (Number of articles; Link Strength)**
Cluster 1 (Red) – 14 items	United States (131; 46), Canada (41; 24), France (38; 26), Germany (36; 14), Iran (30; 13), India (21; 5), Austria (12; 3), Brazil (13; 3), Australia (12; 10), Columbia (8; 7), Denmark (7; 5), Mexico (6; 6), New Zealand (6; 3), Switzerland (6; 5)
Cluster 2 (Green) – 8 items	United Kingdom (43; 26), Italy (29; 15), Belgium (21; 12), Portugal (11; 9), Malaysia (8; 2), Norway (8; 4), Greece (6; 1), Czech Republic (5; 2)
Cluster 3 (Blue) – 5 items	Poland (12; 4), Thailand (12; 2), South Korea (8; 6), Finland (5; 2), Japan (5; 3)
Cluster 4 (Yellow) – 5 items	China (117; 44), Taiwan (21; 9), Hong Kong (17; 7), Netherlands (14; 6), Singapore (8; 7)
Cluster 5 (Purple) – 5 items	Turkey (28; 2), Saudi Arabia (20; 10), Spain (13; 5), Tunisia (6; 4), Egypt (5; 2)

3. Influential articles, authors and journals.

The most cited article in 637 publications was by [23], with 337 citations. This article was published by Management Science in 1993 with a contribution rate of 50.07%. This paper was about how to solve crew scheduling in the airline sector by using the branch-and-cut method. As a result, [23] has been successful in proposing less costly schedules, which increase the crew's happiness with spending less waiting on the ground than flying. Other than that, the second most cited article was by [24]. This article tries to solve the nurse scheduling in a large hospital by using tabu search with strategic oscillation. The author is able to propose an effective method which matches the quality of the solution produced manually. Other than these two articles, the articles with the highest number of citations are listed in Table 4.

Table 4: The most influential article on staff scheduling optimization

No	Title of article	Year	Journal	Total Citations	Contribution rate (%)
1	Solving airline crew scheduling problems by branch-and-cut [23]	1993	Management Science	337	50.07
2	Nurse scheduling with tabu search and strategic oscillation [24]	1998	European Journal of Operational Research	235	34.92
3	A hybrid quantum-inspired genetic algorithm for multiobjective flow shop scheduling [25]	2007	IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics	214	31.80
4	Scheduling jobs with position-dependent processing times [26]	2004	Journal of the Operational Research Society	207	30.76
5	A tabu search algorithm for the multi-trip vehicle routing and scheduling problem [27]	1997	European Journal of Operational Research	175	26.00
6	Metaheuristics for solving a multimodal home-healthcare scheduling problem [28]	2015	Central European Journal of Operations Research	161	23.92
7	Ant colony optimization for software project scheduling and staffing with an event-based scheduler [29]	2013	IEEE Transactions on Software Engineering	155	23.03
8	Continuous-discrete interactions in chemical processing plants [30]	2000	Proceedings of the IEEE	149	22.14
9	Scheduling projects with multi-skilled personnel by a hybrid MILP/CP benders decomposition algorithm [31]	2009	Journal of Scheduling	147	21.84
10	An analytic framework for sequencing mixed model assembly lines [32]	1992	International Journal of Production Research	144	21.40

Table 5: The most prominent authors that actively published staff scheduling optimization articles.

No	Author	Scopus ID	H-index	Scopus		Staff scheduling articles				Current affiliation
				Year of 1st article	Total publications	Year of 1st article	No of articles	Total citations	Contribution Rate (%)	
1	Bard, Jonathan F.	36846249500	55	1978	201	1992	11	339	1.63	The University of Texas at Austin, United States

2	Alfares, Hesham Kamal	6603700178	21	1995	61	1998	10	139	1.49	King Fahd University of Petroleumand Minerals, Saudi Arabia
3	Maenhout, Broos	22980289500	18	2006	53	2010	9	191	1.34	Ghent University, Belgium
4	Vanhoucke, Mario	6602303040	45	1998	213	2010	7	193	1.04	Ghent University, Belgium
5	Gutjahr, Walter J.	55908026700	35	1991	97	2000	6	414	0.89	University of Vienna, Austria
6	Smet, Pieter	55156682100	13	2012	39	2016	5	90	0.74	KU Leaven, Belgium
7	Soumis, François	7003665926	41	1980	146	2007	5	32	0.74	Polytechnique Montreal, Canada
8	Costa, A.	35306649000	21	2001	73	2013	4	137	0.59	University of Catania, Italy
9	Desaulniers, Guy	6603948814	41	1995	140	2007	4	29	0.59	Polytechnique Montreal, Canada
10	Su, Xichao	56611159100	15	2015	56	2018	4	53	0.59	Naval Aviation University, China

Table 6: The most productive journals that actively published staff scheduling optimization articles.

No	**Source Title**	**Total Publications (%)**	**Total Citations**	**Cite Score 2023**	**Highly cited article (Title)**	**Times Cited**	**Publisher**
1	European Journal Of Operational Research	40 (5.94)	1962	11.90	Nurse scheduling with tabu search and strategic oscillation [24]	238	Elsevier
2	Computers And Operations Research	33 (4.90)	666	8.60	Solving software project scheduling problems with ant colony optimization [33]	86	Elsevier
3	Computers And Industrial Engineering	29 (4.31)	630	12.70	Scheduling an operating theatre under human resource constraints [34]	127	Elsevier
4	International Journal Of Production Research	19 (2.82)	562	19.20	An analytic framework for sequencing mixed model assembly lines [35]	144	Taylor & Francis

5	Journal Of The Operational Research Society	16 (2.38)	525	6.80	Scheduling jobs with position-dependent processing times [36]	206	Taylor & Francis
6	Expert Systems With Applications	15 (2.23)	318	13.80	A metaheuristic approach to the integration of worker assignment and vehicle routing problems: Application to home healthcare scheduling [37]	58	Elsevier
7	Journal Of Scheduling	15 (2.23)	334	3.80	Scheduling projects with multi-skilled personnel by a hybrid MILP/CP benders decomposition algorithm [38]	147	Springer Link
8	Health Care Management Science	10 (1.49)	210	7.20	A stochastic optimization model for shift scheduling in emergency departments [39]	59	Springer Link
9	IEEE Access	10 (1.49)	55	9.80	A Robust Scheduling Optimization Method for Flight Deck Operations of Aircraft Carrier With Ternary Interval Durations [40]	18	IEEE
10	Interfaces	9 (1.34)	223	3.20	Bringing robustness to patient flow management through optimized patient transports in hospitals [41]	67	INFORMS

Besides the most influential articles, this paper also analyzed the most prominent authors and journals that actively published articles related to staff scheduling optimization. The results are listed in Table 5 and Table 6, respectively. In bibliometric analysis, examining the most prominent authors and journals is essential for identifying key contributors and leading publications that shape the research trends. This analysis assists in identifying research gaps, promoting high-impact research, monitoring any emergent topics, and keeping future researchers updated on the latest advancements. In the staff scheduling optimization research, Jonathan F Bard, from the University of Texas, United States, was the most prominent author who had published 201 articles in Scopus since 1978. However, in 1992, he started publishing about staff scheduling optimization in Scopus, with 11 articles contributing to 1.63% of the field, which received 339 citations. Meanwhile, the second top author was Hesham Kamal Alfares from King Fahd University of Petroleum and Minerals in Saudi Arabia. He has published 10 out of 61 articles on staff scheduling optimization since 1995, which received 139 citations (1.49%). Broos Maenhout and Mario Vanhoucke follow this list of prominent authors, both from Ghent University, who have contribution rates of 1.34% and 1.04%, respectively.

Meanwhile, in terms of productive journals, the European Journal of Operation Research serves the most published articles in staff scheduling optimization with 40 articles (5.94%). This journal had received 1962 total citations, resulting in 11.90 for the Citescore 2023. The most cited article in this journal that related to staff scheduling optimization was [24], with 238 citations. It was followed by a Computer and Operations Research journal published by Elsevier, which received 8.60 in CiteScore 2023. This journal had 33 articles

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related to staff scheduling optimization, with [33] being the most cited article (86 citations) in this journal. Among the journals listed in Table 6, the highest CiteScore 2023 was the International Journal of Production Research (19.20) by Taylor and Francis. Followed by the Expert Systems with Application and Computer and Industrial Engineering journal with CiteScore 2023 of 13.8 and 12.7, respectively.

B. Keyword occurrences and evolution

In this analysis, the keyword co-occurrences in VOSviewer will be used. The setting will be set to ALL keywords, either identified by the author or the database, which will be analyzed, and only a document with a minimum of 5 occurrences of a keyword will go through the analysis. As a result, 323 out of 4618 keywords met the threshold and visualized in Figure 3. All 323 keywords have been clustered into four clusters, with the keyword "scheduling" being the most popular keyword, with 3296 occurrences and a total link strength of 3017. Followed by "optimization" (265 occurrences; 1923 total link strength) and "integer programming" (139 occurrences; 1118 total link strength). This data shows that the most popular method used in solving staff scheduling optimization is integer programming. Rather than integer programming, the other popular methods used in solving staff scheduling optimization problems are using "genetic algorithm" (73 occurrences; 666 total link strength), "heuristic methods" (58 occurrences; 535 total link strength), "multiobjective optimization" (41 occurrences; 384 total link strength), "linear programming" (44 occurrences; 384 total link strength), etc. The research gaps from this network map can be determined by looking at the link between nodes. If there were no connection between the two keywords, then it would be the research gap for future research on staff scheduling optimization.

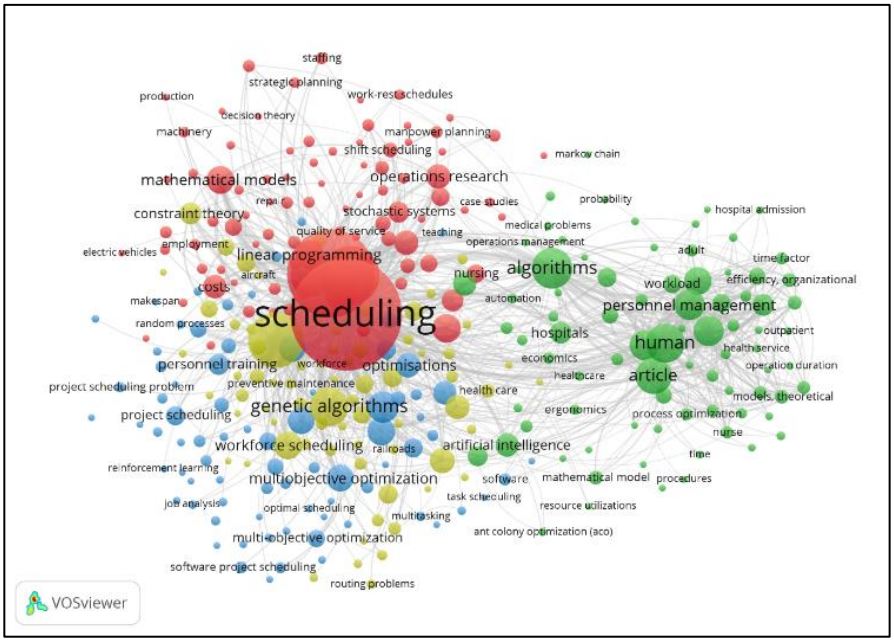

Figure 3: Network visualization map of all keyword co-occurrences from 1981-2023 (Online map: https://tinyurl.com/2gmsxkgz)

Besides discussing the overall keywords used in staff scheduling optimization research, this paper will discuss how the keywords evolved from the initial phase to the exploration phase according to their chronological groups (1989-1999, 2000-2011, 2012-2023). For all these keyword occurrences analysis, the setting will be set to be full counting for all keywords with a minimum of 5 occurrences for each keyword. As a result, in the initial phase, 20 out of 348 keywords have been detected and met the threshold. These keywords were clustering into four clusters with a total link strength of 579, as shown in Figure 4. The most popular keywords in this era were "scheduling" (43 occurrences; 185 total link strength), "optimization" (36 occurrences; 165 total link strength) and "personnel" (26 occurrences; 126 total link strength).

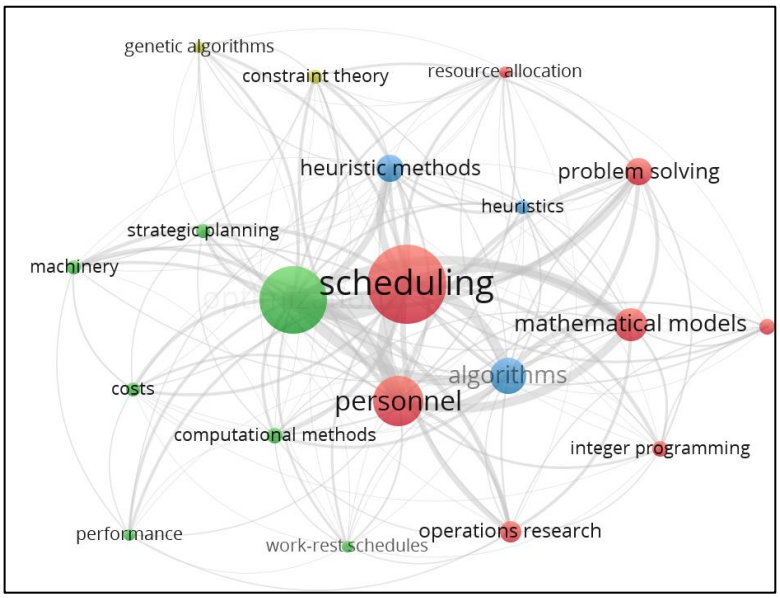

Figure 4: Network node map of the Initial phase of staff scheduling optimization research from 1989-1999 (Online map: https://tinyurl.com/2zu299xk)

Meanwhile, in the next phase, which is the development phase (2000-2011), the keywords have been evolved to be 962 keywords. However, only 42 keywords met the setting and were clustered into 5 clusters with 452 links. The total link strength is 1303, as shown in Figure 5, resulting in a denser network map. The most popular new keywords in this era were “linear programming” (14 occurrences; 83 total link strength), “staff scheduling” (12 occurrences; 57 total link strength) and “mathematical programming” (11 occurrences; 43 total link strength). In this era, we can see that the research trends were more focused on application mathematical programming, which solved a few staff scheduling optimization problems in various sectors.

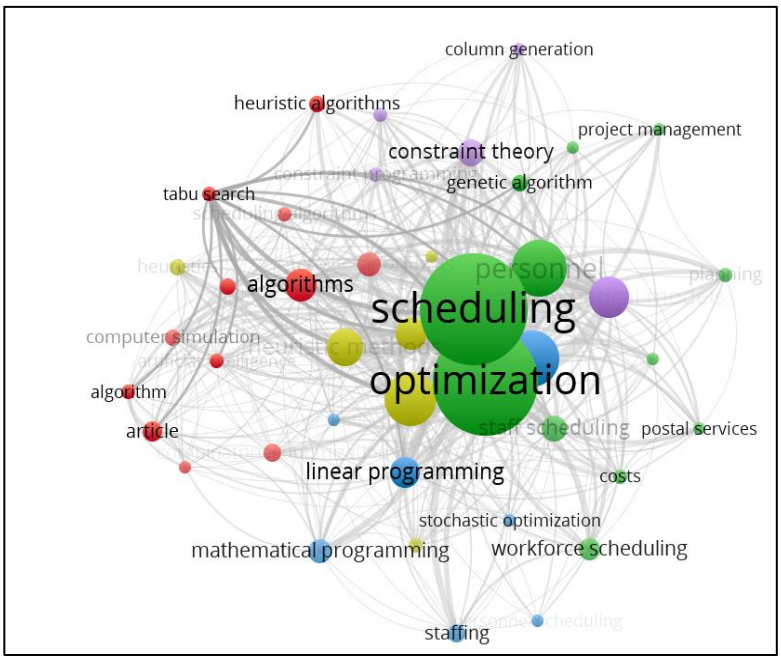

Figure 5: Network node map of the development phase of staff scheduling optimization research from 2000-2011 (Online map: https://tinyurl.com/2fsfr6n6)

Furthermore, Figure 6 shows the denser node map of keywords in the exploration phase (2012-2023), where

3889 keywords were detected in 673 documents. However, only 263 out of 3889 keywords met the setting. These keywords have been clustered into 4 clusters with 8347 links and a total link strength of 17655. The most popular new keywords in this era were “genetic algorithms” (57 occurrences; 476 total link strength), “multiobjective optimization” (38 occurrences; 345 total link strength) and “scheduling algorithms” (37 occurrences; 351 total link strength). In this era, more advanced algorithms have been explored, such as in articles by [29], which used ant colony optimization to develop a flexible and effective model for software project planning by considering task scheduling and employee allocation.

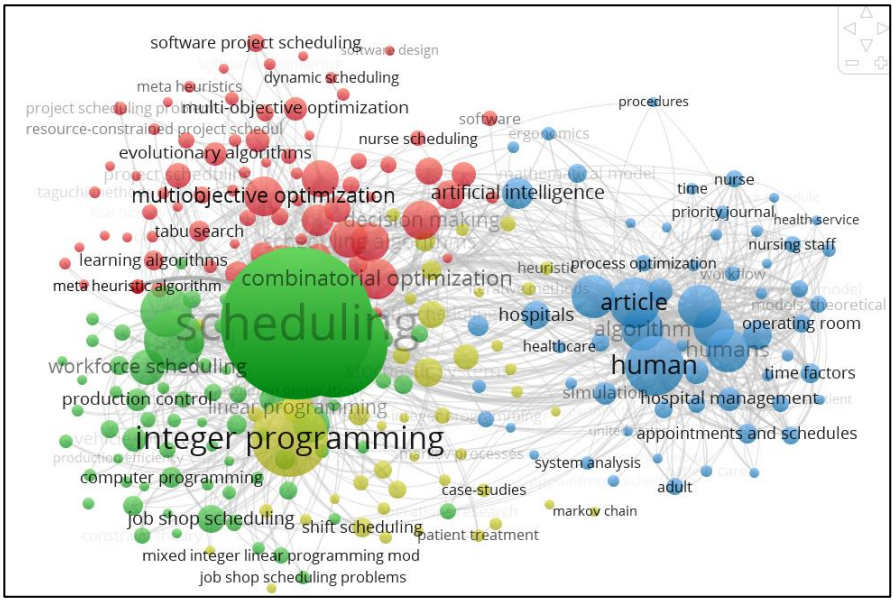

Figure 6: Network node map of the exploration phase of staff scheduling optimization research from 2012-2023 (Online map: https://tinyurl.com/2gfk5vej)

C. Research gaps and future directions

As can be seen from the evolution of keywords and the research trends in terms of publication, there is a need for models that better adapt to dynamic workforce requirements and incorporate human factors. There are a few sectors that still have not received enough highlights from the researchers, such as staff scheduling among the plantation workers or small retailing convenience stores. Therefore, in future research, they should focus on developing scalable and flexible models that incorporate interdisciplinary approaches and address sector-specific challenges.

CONCLUSION

The bibliometric analysis can help in presenting valuable insights into the current research trends and areas that need extra attention in the specific research topics. This paper has analyzed 673 articles related to staff scheduling optimization that were published in the Scopus database from 1989 to 2023. This bibliometric review highlights the significant growth in staff scheduling optimization research, with notable contributions from various authors, countries and journals. Besides that, the evolution of keywords was also highlighted in this paper. The analysis in this paper was conducted using Microsoft Excel and VOSviewer software, which covers 77 countries, 158 journals, 160 academic institutions, 160 authors, and 3889 keywords.

The findings in this paper will help future researchers plan future international collaboration in order to exchange ideas and knowledge with other researchers. Besides that, the keywords collaboration can also create a new research gap for future research related to staff scheduling optimization. As the field of staff

scheduling optimization evolves, ongoing research must continue to innovate and address real-world scheduling challenges by creating a new model to meet the dynamic workforce needs.

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