



(REVIEW ARTICLE)



A bibliometric analysis and visualization of sustainable production scheduling

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Abstract

Future shortage of material and energy resources also scarcity that might happen in manufacturing world have become public interest in world. This challenge build innovative needs like resource-efficient engineering, as the transition from a linear to a circular economy. There are more researches on energy-efficiency in many kind of manufacturing settings, including scheduling As a result, there have been numerous studies on sustainable production scheduling reviews, but only a few have documented the literature. This paper aims to provide summary of existing researches by bibliometric analysis. Bibliometrics is the interdisciplinary science of quantitative analysis of all knowledge carriers mathematical and statistical methods and a commonly used method of identifying developments from certain fields

Keywords: Sustainable; Production; Scheduling; Bibliometric Analysis; VOS Viewer

1. Introduction

Future shortage of material and energy resources also scarcity that might happen in manufacturing world have become public interest in world [1]. This challenge build innovative needs like resource-efficient engineering, as the transition from a linear to a circular economy. One of the dominant sector that resulting directly or indirectly emission of carbon dioxide is manufacturing enterprises [2]. Modern manufacturers not only like to minimize total costs but also environmental impacts as well such as Toyota [3]. There are more researches on energy-efficient in many kind of manufacturing settings, including scheduling[4].

Sustainable manufacturing is substantiated by concepts such as conservation of energy, material and value-added products, waste prevention and environment protection [5]. One of the many methods of reaching energy efficiency in manufacturing is to handle the production scheduling function by considering social metrics, green metrics alongside traditional performance indicators [6].

As a result, there have been numerous studies on sustainable production scheduling reviews, but only a few have documented the literature. This paper aims to provide summary of existing researches by bibliometric analysis. Bibliometrics is the interdisciplinary science of quantitative analysis of all knowledge carriers mathematical and statistical methods and a commonly used method of identifying developments from certain fields [7]. The rest of this paper is organized as follows: in Section 2, we introduce the data and methods used in this study, Section 3 illustrates the results in detail with some illustrations that drawn by VOS Viewer and last, Section 4 summarizes the whole paper and the results are discussed in this section

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2. Data and Methods

The data that used in this paper were downloaded from Scopus. This paper the combination word between “sustainable” and “production scheduling” with the time span was defined from 2011 until 2021. Based on the research through Scopus, there are 559 documents that related to these 2 keywords. 296 document types were found in article category, 180 documents in conference paper category, 36 documents in conference review, 17 in book chapter and 24 in review. Based on that data, we know that the most frequent document type is article category. Meanwhile in emerald, there are 6000 documents that found in sustainable production scheduling area. After that, some filtering process are performed. The first filtering step is by reading titles and keyword that relevant with sustainable production scheduling in industrial field, the result is there are 543 documents that found relevant. The reason why many papers that are not taken because mostly sustainable production scheduling were found in irrigation system and not related with the production scheduling in manufacturing system.

The second step filtering process is by reading abstract, the total papers that are chosen is 325 papers, the reason is other papers are talking about machine development not production scheduling. The last step filtering process is by do reading full contents and there are 55 papers that are relevant to production scheduling and chosen to be analyzed.

All documents were downloaded through Scopus and extracted them to csv file and proceed it by VOS Viewer. VOS Viewer is a free software developed by Eck and Waltman to help co-occurrence and co-citation analysis and do mapping that will be discussed more in the upcoming section.

3. Results

This section may be divided by three subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

3.1. The Current Status of Supply Chain Challenge: Congestion Study

In this section, we discuss the annual trends of Supply Chain Challenge: Congestion related publications and distributions publications in the perspective of institutes and journals, as well as citation and H-index analysis.

3.1.1. The Annual Trend of Supply Chain Challenge: Congestion Study

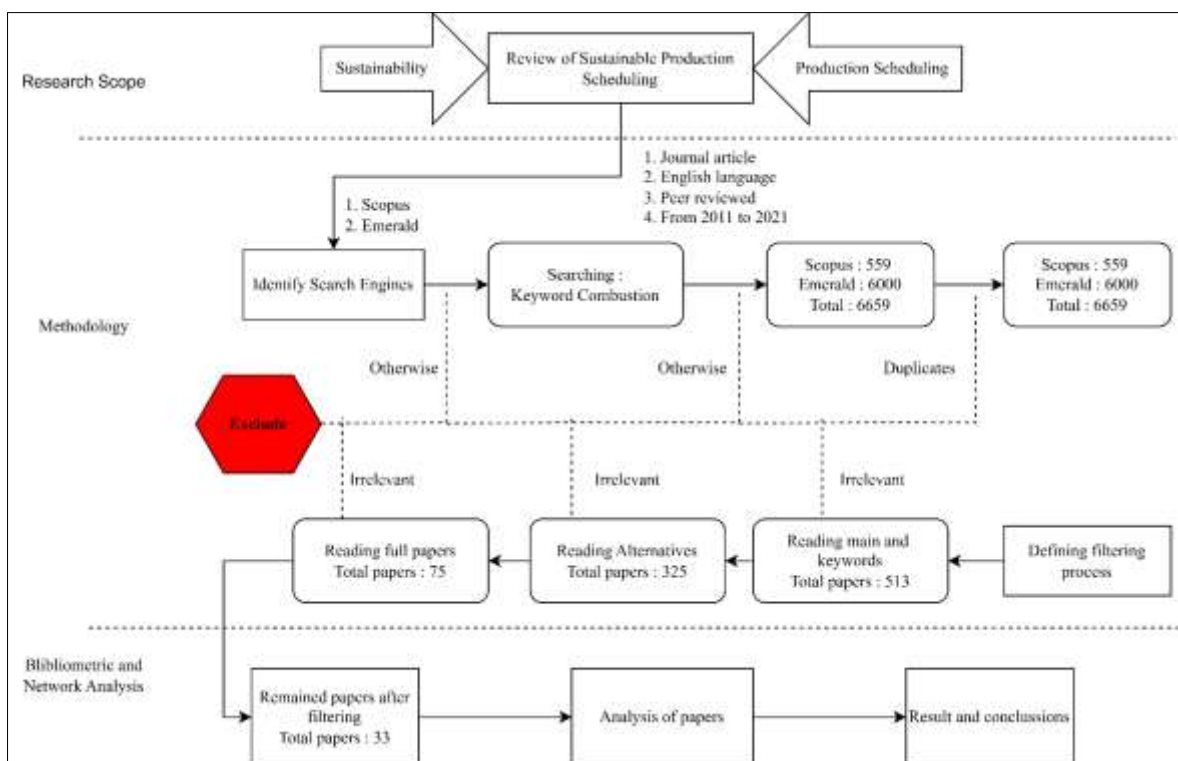


Figure 1 Filtering Methodology

Figure 1 illustrates the plot of the annual trend of Supply Chain Challenge: Congestion publications. The first publication was released in 2010 then continued to fluctuate and reached its peak in 2020. This was due to the COVID-19 pandemic which caused changes in supply chains and pressures for sustainability got bigger attached people to take focus on this study.

The first paper that released in 2011 mostly discussed about water efficiency, irrigation strategies and forest management. These papers talked about water because water management efficiency is a key issue for sustainable agriculture development, since it is to get a higher biomass production per unit of applied water. This study aimed to determine both water requirements and water use efficiency also their effect on yield and quality parameters in carrots plan.

In 2019 and 2020, Sustainable Production Scheduling related publications got its peak with a total 87 and 82 publications. Most of them already focused on green scheduling with developing metaheuristic methods such as Genetic Algorithm, Particle Swarm Optimization, etc. Rubaiee et al (2019) discussed single machine scheduling problem that focuses on minimize the total tardiness and total energy cost with a mixed-integer multi-objective mathematical programming model while at the same time developing Genetic Algorithm [6]. The proposed model includes a weighted sum method and multi-objective genetic algorithms. Figure 2 illustrates the annual trend of Sustainable Production Scheduling publications with a graph.

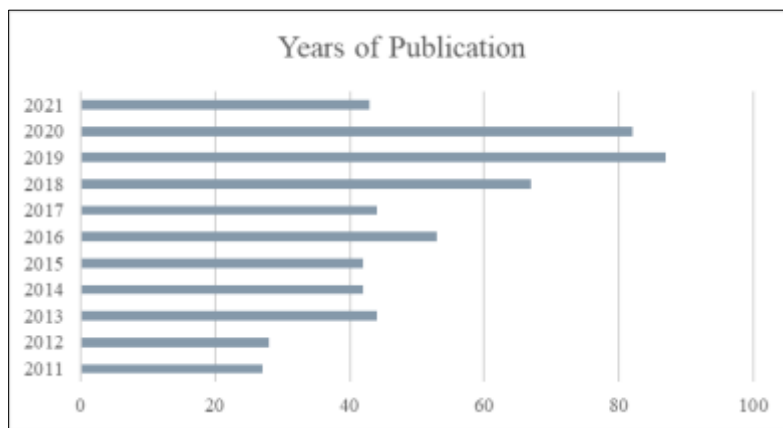


Figure 2 Annual Trend of Sustainable Production Scheduling Study

3.1.2. The Distribution of Institutes on Sustainable Production Scheduling Study

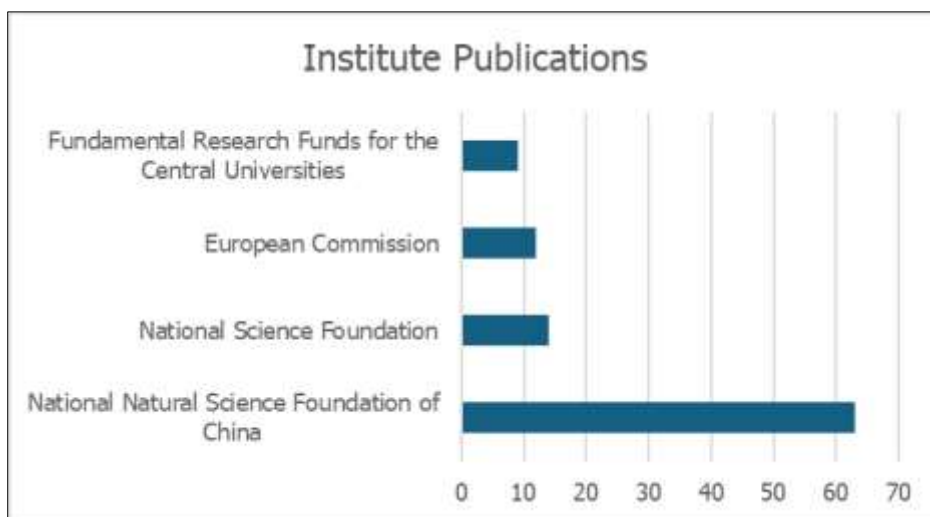


Figure 3 The Institutes with Sustainable Production Scheduling Study Related Publication

The institute that currently leading in Sustainable Production Scheduling related publications is National Natural Science Foundation of China with a total of 63 papers. Dhungana et al (2021) developed production scheduling with

combination of Industrial Internet of Things (IIOT) and Edge Computing (EC) and can improve energy efficiency up to 26%. Meanwhile Duan, et al (2021) discussed a new sustainable scheduling approach of mixed-line production that considers carbon emission and make span formulations related to cutting, welding and heat treatment. In order to solve the model, the genetic algorithm is improved. There are other institutions that followed as depicted in Figure 3.

3.1.3. The Distribution of Published Journal on Sustainable Production Scheduling Study

All 55 papers that related to Sustainable Production Scheduling published in 7 journals as depicted in Figure 4. Most papers published in Journal of Cleaner Production with a total of 48 papers. Figure 4 illustrates The Distribution of Published Journal on Sustainable Production Scheduling Study, it mainly published in Journal of Cleaner Production since the objective that used is to minimize energy and emission of carbon to make production goes more sustain and efficient. Also, most papers published in IFIP Advances in Information and Communication Technology because most of production scheduling are np hard problem and solved by software such as heuristic and meta heuristic methods.

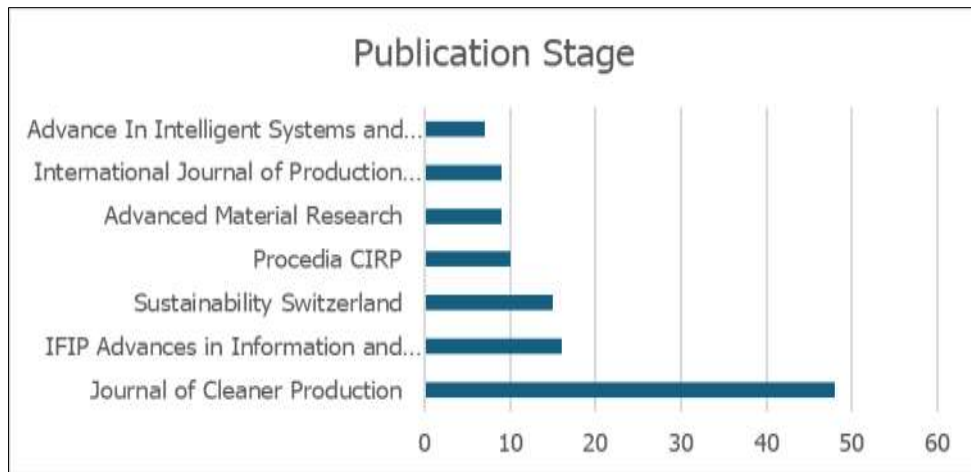


Figure 4 The Journal with Sustainable Production Scheduling

3.1.4. The Citation and H-Index Analysis

The number of citations is a major factor to depict the quality of a publication. Based on Figure 5, the country that has most published research about Sustainable Production Scheduling and has the greatest citation numbers is China with total of 123 publications and 748 citations.

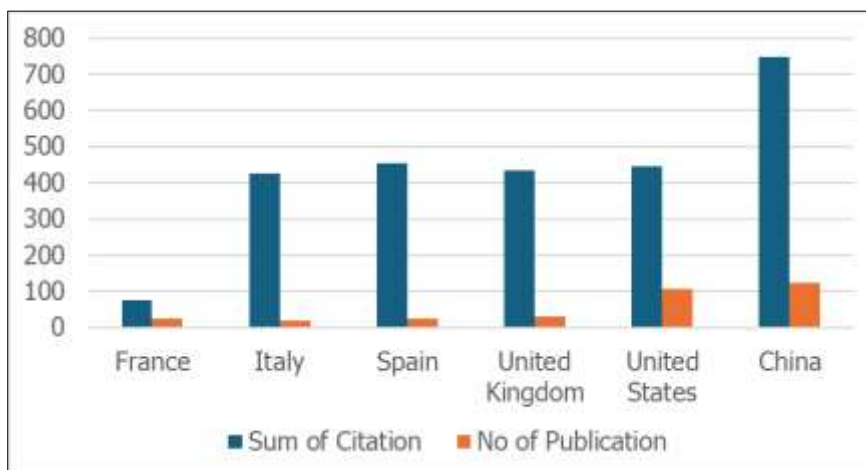


Figure 5 Sum of Citation and Number of Publication on Sustainable Production Scheduling Study

The paper that has biggest H-Index was written by Liu et al [19-20] . They developed a new joint production scheduling model considering energy and maintenance implementation to minimize energy consumption and throughput improvement using meta heuristic methods, Particle swarm optimization. The main objective is to solve the cost

minimization problem to find a near optimal solution of production and maintenance schedules. The result is the method can reduce cost per unit production up to 27% compared to the existing strategies.

3.2. The Keyword Analysis of Research on Sustainable Production Scheduling

In this section, we study content by analyzing co-word distribution. The co-word network visualization was made to identify the major words that mentioned in papers and to identify the gap in related field. To obtain this map, co-occurrence was selected the map was built by VOS Viewer. The total keywords that linked were 39 words with a threshold of five occurrences was set.

Based on figure 6, the size of the nodes or the words represent the weight of the nodes, the bigger node or word means the bigger the weight. The line that linked between two points represents the relationship between two nodes. More short distances indicate a stronger relationship. The keyword “scheduling” has a highest total link strength of 252. The other most frequent keywords are “energy utilization”, “production control”, ‘sustainable development” and “job shop”.

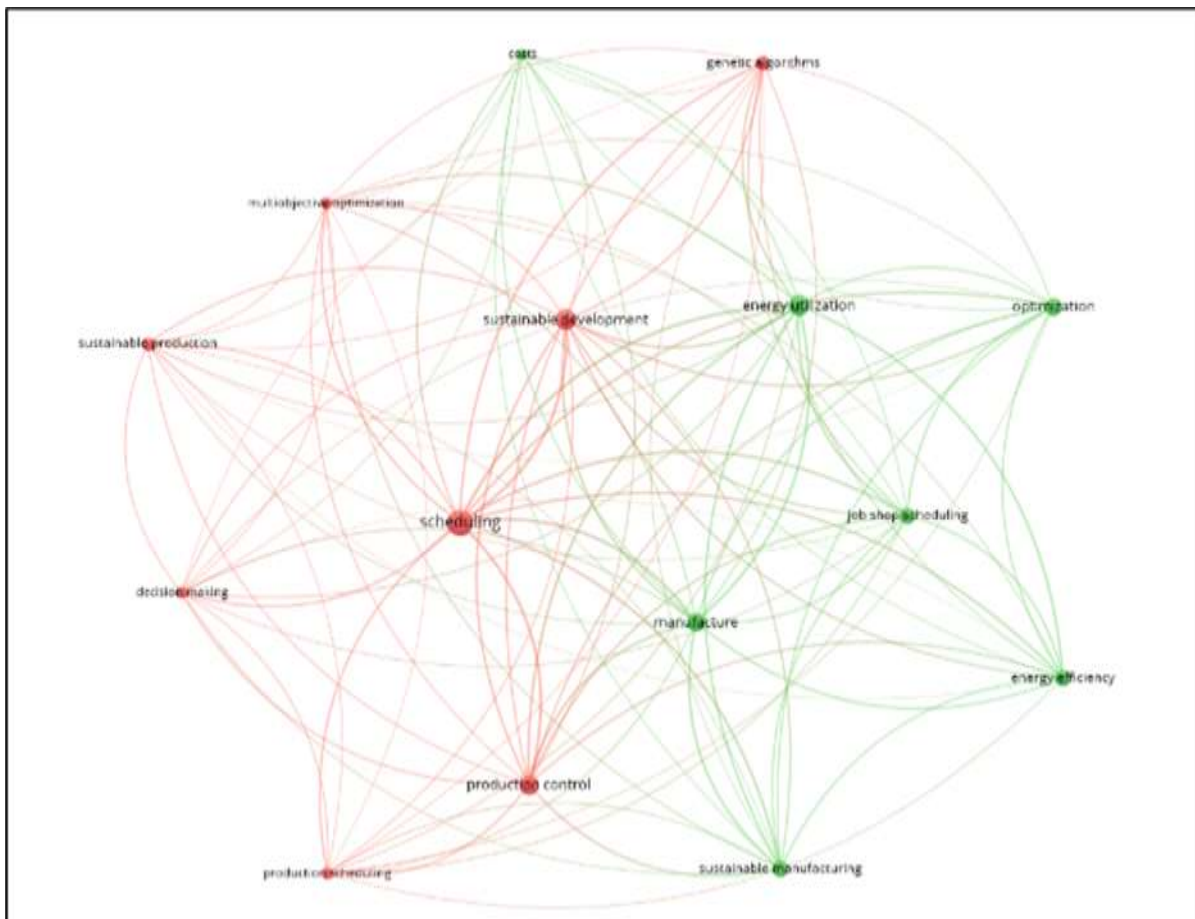


Figure 6 Co-Occurance Mapping of Sustainable Production Scheduling

The link strength between two nodes refers to the frequency of co-occurrence. The total link strength of a node is the sum of link strengths of this node over all the other nodes. The keyword or node of “schedule” has thicker line on “sustainable development”, “energy efficiency” and “sustainable development”. Meanwhile the node of “sustainable development” has thicker line on “energy efficient”, “optimization” and “genetic algorithm”. It reflects that mostly sustainable production scheduling research still in energy efficiency area with optimization type and because sustainable production scheduling is np hard problem, it solved by metaheuristic method such as Genetic Algorithm. The top 10 keywords with their frequencies and total link strengths are shown in Table 1.

Table 1 Co Occurrence of Sustainable Production Scheduling

Keyword	Frequency	Total Link Strength
scheduling	50	252
energy utilization	32	186
production control	29	164
manufacture	27	161
sustainable development	34	160
job shop scheduling	21	126
sustainable manufacturing	22	121
energy efficiency	21	119
optimization	23	105
genetic algorithms	16	89
multi-objective optimization	12	73
decision making	12	70
production scheduling	12	68
sustainable production	14	61
Costs	8	59

3.3. Evolution of Research Internets

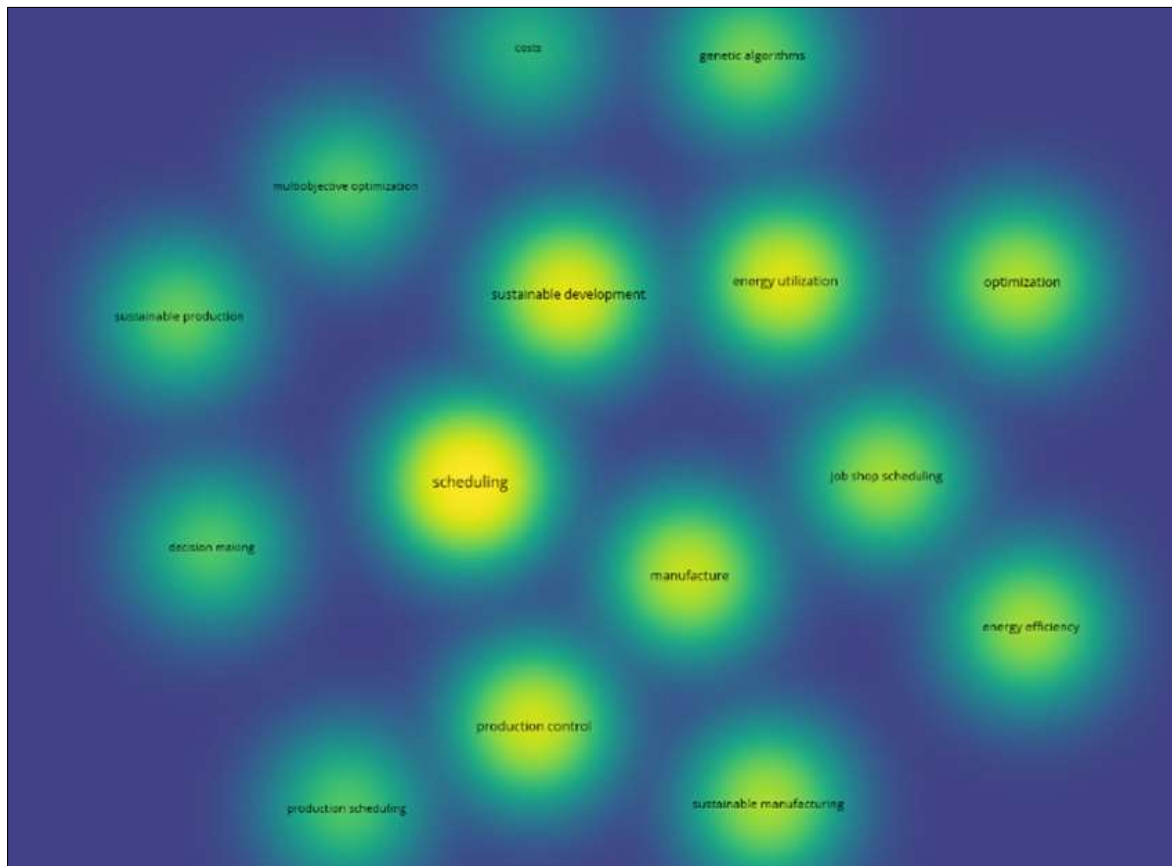


Figure 7 Density Visualization of Sustainable Production Scheduling

VOS Viewer can make density visualizations (see Figure 7). Each node has a keyword has its density and its density color. In other words, the color node depends on the number of items in the node environment. The red area means the topic appears more frequently, conversely, keywords in the green area appear less frequently. Based on Figure 7, there are already many publications that talked about scheduling, sustainability, energy utilization. Meanwhile there is still few publications that considers sustainable production with cost, because mainly in sustainability area lot of papers already consider from economic and environmental side but still rare to find that considers both triple line bottom in multi-objective sustainable production scheduling so this can be a big opportunity for the future research.

VOS Viewer also can make overlay visualizations (see Figure 8) that can be used to show developments over time. Based on Figure 8, in 2018 there are some multi-objective, as the time goes by around 2019 it got more topic such as sustainability.

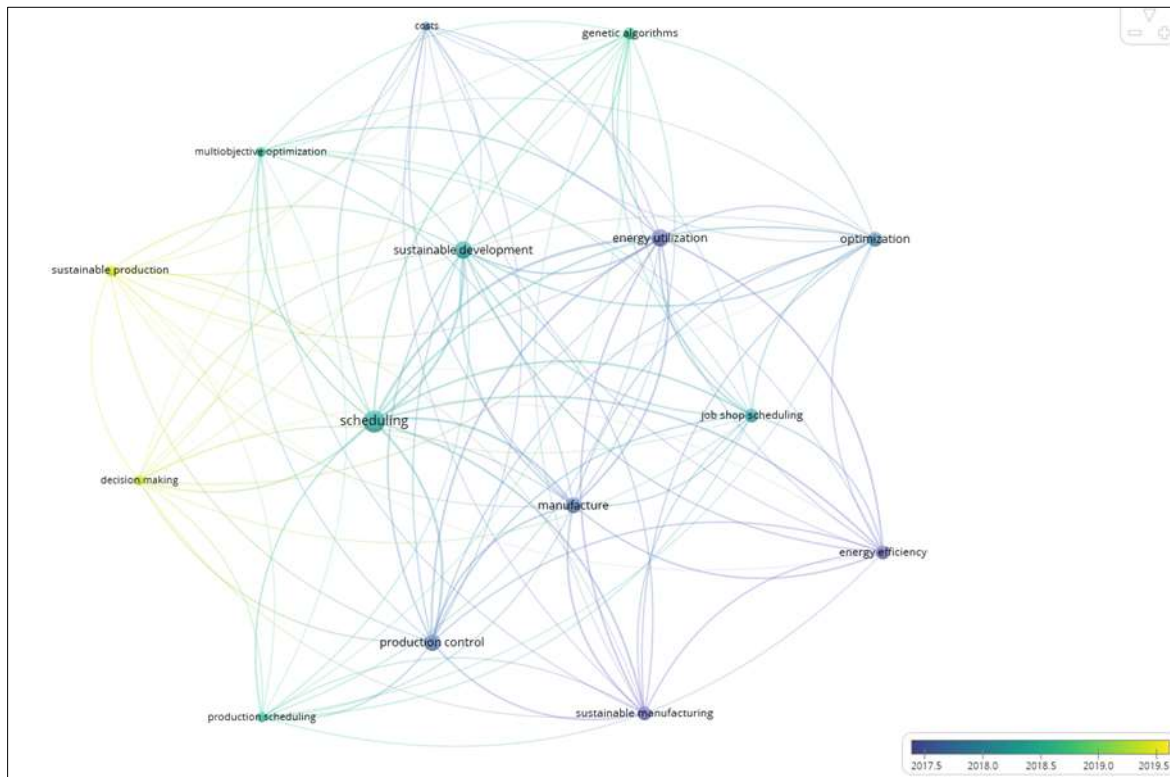


Figure 8 Overlay Visualization of Sustainable Production Scheduling Publications

3.4. Evolution of Sustainable Production Scheduling Indicator

Production scheduling has been developed since 1950, but for mainly focus on green scheduling is still a new one [5]. However, in existing research papers, few researches consider energy cost for scheduling optimization, meanwhile, energy cost is keep going up [9]. Due to the rapid growth of energy demand and challenge of environmental issue and to achieve circular economy, there is the need to develop new objectives in order to change the point of view of optimization and to evaluate the trade-off between economic performance indicators and new green performance metrics, particularly when these objectives are in conflict with each other.

In Hesran et al (2018) the total inventory represents all products finished earlier must be stored until the due date since it related with holding cost [7].

Table 2 Previous research

Author & Years	Method	Economic		Enviromental		Social
		a	b	c	d	
May et al (2015)	Genetic Algorithim	•		•		
Tang et al (2015)	Particle Swarm Optimization	•			•	
Yildirim & Mouzon (2012)	Genetic Algorithm	•			•	
Wang et al (2016)	Integer Programming	•			•	
Salido et al (2016)	Genetic Algorithm	•			•	
Piroofzard et al (2016)	Genetic Algorithm	•		•		
Mansouri et al (2016)	Tailor Based Algorithm	•		•		
Hesran et al (2018)	Mixed Integer Linear Programming		•		•	

a. Makespan b. Inventory c. Carbon Emission d. Energy Consumption

3.5. Multi-Objective Method

A Multi-objective Optimization seeks to determine a vector of decision variables within a feasible region to minimize a vector of objective functions that usually conflict with each other or to combine multiple function that has different metrics [1]. If we want to optimize scheduling that considers triple line bottom it will be a multi-objective scheduling problem. Mostly common approaches that are used in multi-objective problem are: sequential optimization, weighting method, constraint method, goal programming, goal attainment, and distance-based and direction-based methods [10]. The equation of weighted sum of both objectives [3] was used that is shown below:

$$f(w_1, w_2) = w_1 f_1 + w_2 f_2$$

Usually in meta heuristic method, the multi-objective functions are gathered in one function called fitness function, Fitness functions are used to determine the quality of the solutions in current population [3].

4. Conclusion

This study made a bibliometric analysis and mapping related to Sustainable Production Scheduling which can be summarized as follows: First, Sustainable Production Scheduling was first discovered in in 2011 mostly discussed about water efficiency, irrigation strategies and forest management. These papers talked about water because water management efficiency is a key issue for sustainable agriculture development, since it is to get a higher biomass production per unit of applied water. This study aimed to determine both water requirements and water use efficiency also their effect on yield and quality parameters in carrots plan.

In 2019 and 2020, Sustainable Production Scheduling related publications got its peak with a total 87 and 82 publications. Most of them already focused on green scheduling with developing metaheuristic methods such as Genetic Algorithm, Particle Swarm Optimization, etc. Rubaiee et al (2019) discussed single machine scheduling problem that focuses on minimize the total tardiness and total energy cost with a mixed-integer multi-objective mathematical programming model while at the same time developing Genetic Algorithm.

Second, the co-word analysis depicted “The keyword “scheduling” has a highest total link strength of 252. The other most frequent keywords are “energy utilization”, “production control”, ‘sustainable development” and “job shop”. The link strength between two nodes refers to the frequency of co-occurrence. The total link strength of a node is the sum of link strengths of this node over all the other nodes. The keyword or node of “schedule” has thicker line on “sustainable development”, “energy efficiency” and “sustainable development”. Meanwhile the node of “sustainable development” has thicker line on “energy efficient”, “optimization” and “genetic algorithm”. It reflects that mostly sustainable production scheduling research still in energy efficiency area with optimization type and because sustainable production scheduling is np hard problem, it solved by metaheuristic method such as Genetic Algorithm

Third, Based on Figure 8, there are already many publications that talked about scheduling, sustainability, energy utilization. Meanwhile there is still few publications that considers sustainable production with cost, because mainly in

sustainability area lot of papers already consider from economic and environmental side but still rare to find that considers both triple line bottom in multi-objective sustainable production scheduling so this can be a big opportunity for the future research especially adding social indicators such as material hazard or health hazard because of machine that are being used in manufacture process. For combine multiple functions, some method can be used such as sequential optimization, weighting method, constraint method, goal programming, goal attainment, and distance-based and direction-based methods. Other than this, for future research can use others metaheuristic methods beside Genetic Algorithm and Particle swarm Optimization such as Ant Colony Optimization (ACO), Crownsearch Algorithm etc and do compare the performa with GA and PSO algorithm.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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