Operational Research in Engineering Sciences: Theory and Applications
Vol. 6, Issue 2, 2023, pp. 336-366
ISSN: 2620-1607
eISSN: 2620-1747
DOI: https://doi.org/10.31181/oresta/0602117

COST FACTOR FOCUSED SCHEDULING AND SEQUENCING: A NEOTERIC LITERATURE REVIEW

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Received: 21 January 2023
Accepted: 23 March 2023
First Online: 06 April 2023

Research Paper

Abstract*: The hastily emergent concern from researchers in the application of scheduling and sequencing has urged the necessity for analysis of the latest research growth to construct a new outline. This paper focuses on the literature on cost minimization as a primary aim in scheduling problems represented with less significance as a whole in the past literature reviews. The purpose of this paper is to have an intensive study to clarify the development of cost-based scheduling and sequencing (CSS) by reviewing the work published over several parameters for improving the understanding in this field. Various parameters, such as scheduling models, algorithms, industries, journals, publishers, publication year, authors, countries, constraints, uncertainties, computational time, and programming languages and optimization software packages are considered. In this research, the literature review of CSS is done for thirteen years (2010-2022). Although CSS research originated in manufacturing, it has been observed that CSS research publications also addressed case studies based on health, transportation, railway, airport, steel, textile, education, ship, petrochemical, inspection, and construction projects. A detailed evaluation of the literature is followed by significant information found in the study, literature analysis, gaps identification, constraints of work done, and opportunities in future research for the researchers and experts from the industries in CSS.*

Keywords*: Scheduling, Sequencing, Cost, Literature review.*

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1. Introduction

Scheduling is a method that determines when a specific task can be feasibly accomplished. It is a decision-making procedure that optimizes one or more objectives (Pinedo, 2005). The purpose of the scheduling process is thus to decrease the end time of the task and to curtail the cost associated with completing that task. Therefore, for decades, the study of scheduling problems concentrated on reducing objectives like average flow-time, maximum tardiness, and makespan. For these objectives, delaying the completion of the tasks affects a greater cost. However, the present attention in the firm is on just-in-time (JIT) thinking, which assists the view that not only tardiness but earliness also should be dejected. This has inspired the research of scheduling issues where tasks are favoured to be completed just at their individual due dates, and both early and tardy jobs are penalized. (Sidney, 1977) introduced the concept of the earliness and tardiness (E/T) problem; later, many authors concentrated on the notion where the processing times and due dates are specified. Broad reviews are seen in (Baker & Scudder, 1990; Gordon et al., 2002; Kenneth & Gary, 1990; Lauff & Werner, 2004). Thus, during this period, the study of penalties due to E/T scheduling problems was studied extensively in the form of mathematical models. Stanković et al. (2020) provided a model for resolving the flexible job shop scheduling problem (FJSP) that is based on meta-heuristic algorithms, tabu search (Stanković et al., 2020), genetic algorithm (GA), and ant colony optimization. Later on, researchers felt a need to develop advanced computational algorithms for easy and quick solutions in cost minimization considering the E/T scheduling problems. This research was done exhaustively in the next decade; therefore, the review concentrates on the study published after the year 2010.

Imitation of research, points of argument and conclusions necessitate more perspicuous and logical techniques. To the authors' best knowledge, not many studies have been done previously which analyse the research articles extensively in terms of scheduling and sequencing and classified them on the various parameters. Therefore, a more classified review is required that reveals the current situation, mentions the growth of CSS, and discusses the research over multiple parameters. This research work aims to elaborate on explaining emerging scenarios, developments, and the significance of scheduling and sequencing for minimizing cost by studying the published work over various parameters for superior comprehension of the research area for which the study is done in journal articles published between 2010 and 2022.

2. Background of scheduling and sequencing

The scheduling models can be classified by identifying the resource arrangement and the jobs' nature (Baker & Trietsch, 2009). To be more precise, a model may consist single machine or multiple machines. It may be static or dynamic. Dynamic models are essential from practical judgment, but still, static models are widely considered since they are useful to know the fundamentals. Bari and Karande (2021) ranked the sequencing rules in dynamic job shop applying the PROMETHEE-GAIA method (Bari & Karande, 2021). Investigation of static problems usually discovers useful understandings, and later heuristic methods are used in the dynamic approach. Finally, the model may be deterministic or stochastic.

Usually, a client gives a common due date which is considered external or may be considered by the company itself as internal. Common due date related to the system in which various jobs/tasks are to be accomplished altogether. This common due date model is generally applicable in the chemical and food production industries. Here usually more or less, the substances or components used for the whole mixture or the end product have a limited/short period of existence which forces a common due date concept (Yin et al., 2012). In general, these due dates arise from negotiations with clients. Particularly when the company does not know in advance, as the job handled by the company may be part of new work, in such a situation, the due date may be used as a decision factor surrounded by the limitations of the scheduling. Apart from this, most of the time, the job's processing times are unknown with surety. This hypothesis is rational wherever a) the scheduler cannot find production processing times with exactness, b) if the methods of measuring these times consist of faults, and c) the machine or the operator is dependent on arbitrary variations or while the machine set up times vary haphazardly. This ambiguity may exemplify the in-built threat of the company's failure consisting of processing times of the tasks. This characteristic represents a stochastic concept. A usual methodology is to have the processing time of tasks as an arbitrary factor with a given distribution and find a schedule and due dates to optimize a specific criterion (Lemos & Ronconi, 2015).

(Oyetunji, 2009) discussed 29 performance parameters of scheduling as objective functions based on key parameters such as completion time, flow time, lateness, late or tardy jobs, tardiness, earliness, and early jobs. Apart from these traditional parameters, the cost is considered due to the JIT concept. This concept affects the overall cost of a product, which focuses not only on job delay but also on the job that completes before the due date. The literature on scheduling work mainly consists of the performance criteria like completion time, flow-time, tardiness, and earliness. (Çetinkaya & Duman, 2021) proposed a method for reducing the completion time of sub lots and job lots with a single task and many jobs. However, achieving due dates is also one of the important goals. In traditional scheduling methods, due dates are expected to be given externally. Still, they are determined by seeing the system's capability to accomplish the given delivery dates. As a result, in several research works, it has been observed that due-date allocation is a portion of the scheduling process. Generally, it is expected to finish the job as early as possible. However, the theory of JIT production supports the idea that tardiness, as well as earliness, should be discouraged. Costs related to E/T are some of the common criteria considered for finding the performance of the production.

In sequencing, taking into consideration the due dates, the key factor is normally to complete all the jobs on time. If due dates are unrestricted, apparently, this intent may be accomplished by allowing the loose due dates. Still, in a condition wherein due dates can be carefully selected, it is intended to allot due dates to be tight as probable, which is a restricted one. Tight due dates, bid more clients than due-dates which are loose in a marketplace full of competition and specify better client facility. Tighter due dates also have an affinity to yield smaller inventory levels; hence they are essential for scheduling (Callagher & Cullis, 2021).

3. Research approach

Reviewing the literature is a typical technique to explore various methods of the topic to be studied exhaustively. In this study, a simple research process is followed that includes a literature review with respect to the development of scheduling and sequencing with cost minimization as a primary aim. This review uses a classification scheme to present existing work, identifies some gaps, and provides ideas for further investigation related to the topic. The research approach used for this study is shown in Figure 1. This work is studied extensively and explored in the last decade. Therefore, the existing work published in peer-reviewed publications between 2010 and the present year is considered for review. The articles having the word "Scheduling and Sequencing" in the title, abstract and keywords are searched from the Scopus database. On June 29, 2022, the last search for updating was conducted. A total of 2026 research papers were found. This comprised several objectives, with cost being the most important. As a result, the word "cost" was searched in the abstract. 430 research papers were found with cost as an objective. The work does not consider book chapters, conference papers, PhD and master's degree theses, news reports, or textbooks.

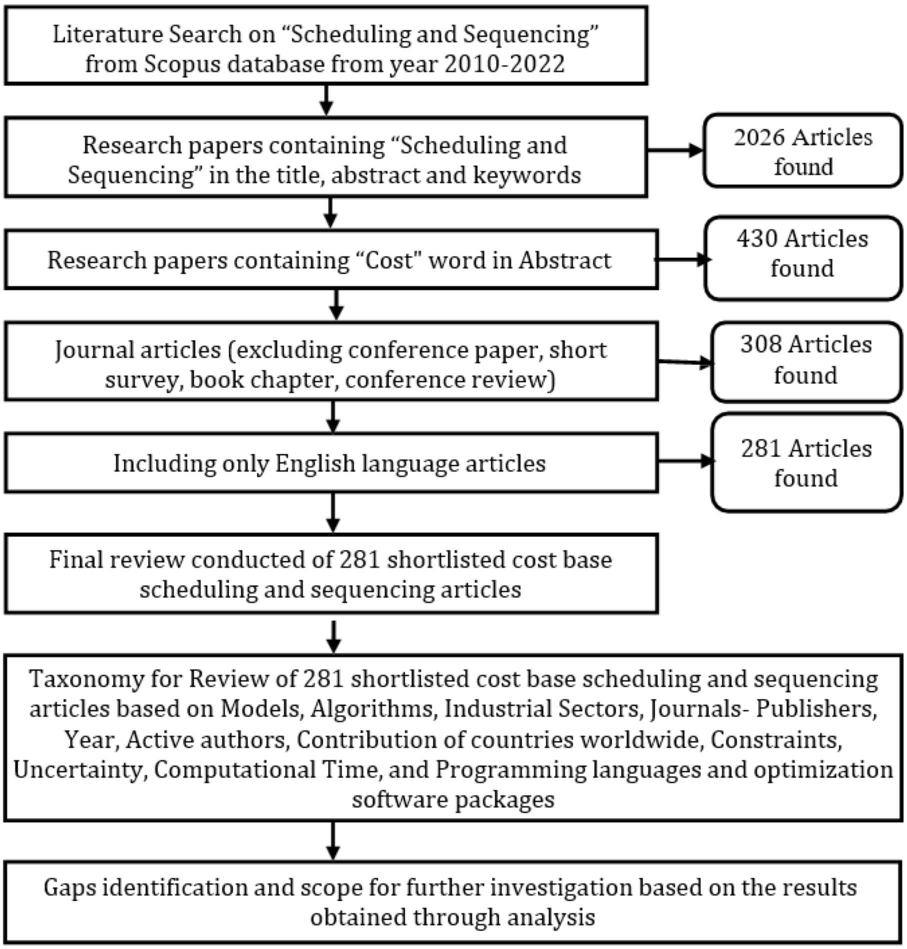


Figure 1. Framework for research study

Considering the research on scheduling, it would be tough to take the literature under all the categories. Thus databases of a peer-reviewed journals are selected and surveyed to present work done on scheduling under one umbrella. Journals from well-known publishers such as Elsevier, Springer, Taylor and Francis, IEEE, INFORMS, and others are considered. These databases permit to access full-text to many good research papers and journals, which include a variety of collections for social and applied science subjects comprising management and business areas, engineering, health, and computer science. In the above-stated databases, the search brings in 281 journal research papers from 153 journals. There were few research papers found with aforesaid mentioned search words, for example, the paper titled "A statistical approach to selecting and confirming validation targets in -omics experiments" but did not consider in the literature as it was not focused on the CSS topic. An attempt has been made to gather information from all the related research papers. It is anticipated that the projected methodology, concepts, considerations of grouping, and interpretation of the study will be suitable means for research scholars and practitioners, who are connected in research of cost optimization in scheduling and will support to encourage advanced study in this field.

4. Classification framework

After going through the work on CSS according to the methodology mentioned in section 3, a method of classification framework is put forward. After study and analysis of existing work in CSS, the proposed classification is explained with eleven main dimensions as: Scheduling Models, Algorithms Used, Industrial Sectors, Journals and Publishers, Publication Year, Authors in the study, Contribution of countries worldwide, Constraints, Uncertainties, Computational Time and Programming languages and optimization software packages.

The classification framework expedites the CSS research in different ways for imminent researchers. The scheduling model will help to tackle real-world problems in industries. The classification of algorithms expresses how a near-optimal answer for the research aim in CSS can be attained. Industrial sectors help in choosing case studies for scheduling and sequencing. Journals and Publishers' classification focuses on where more work related to CSS has been published. Publication Year states the trend in CSS study over the past thirteen years. The authors in the study support bringing up the work in related research. Countrywide classification speaks geographical location where the research is carried out. Constraints taxonomy helps researchers know what constraints are in scheduling and sequencing to achieve the goal related to specific industrial sectors. The uncertainties section conveys how authors control the uncertainty in the CSS study. The Programming languages and optimization software packages section gives an idea of which software can be used to perform computations and automate the optimization process. This study will guide the pursuit of comprehensive research by describing the historical growth, application areas, challenging concepts in the research, and the most important sources of CSS data.

5. Study of the classification scheme

5.1. Classification of research papers on scheduling models

5.1.1. Single and Multiple machines

In practice, the industry may have more than one machine. So it is logical to study the concept of jobs being scheduled on multiple machines, which increases the difficulty of the problem. However, the concept of a single machine is still by large under study by the authors, which helps to understand the fundamental knowledge. It has been observed from the literature that almost 70% of the CSS work is carried out on a single machine, and on the other hand, approximately 30% of the work is performed on multiple machines.

5.1.2. Static and Dynamic

In a static model, the number of jobs that are scheduled on a machine is fixed over a given period. Static models are useful for understanding the fundamental theory of scheduling and sequencing. Xianru (2012) developed a model for sequencing static aircraft arrival and solving scheduling problems of their landings to reduce overall costs in delay (Xianru, 2012). In a dynamic model, the number of jobs that are scheduled on a machine is not fixed over a given period, and new jobs continuously appear over time. In real-world judgement, dynamic models are more vital. Generally, heuristic methods are used in the dynamic approach. Kobayashi (2021) applied a model on a printed circuit board that includes a multi-item single-machine dynamic lot size to achieve the optimal solution in scheduling (Kobayashi, 2021). Lakhan et al. (2022a) proposed an algorithm based on a neural network for partitioning and scheduling in the health sector that accepts dynamic changes concerning network content and resource setting to minimize energy consumption and overall cost (Lakhan, Mastoi, et al., 2022). Zhang et al. (2021) developed a collaborative approach to increase the efficiency of genetic programming in dynamic (Zhang et al., 2021), flexible job shop scheduling and showed that the computational cost could be reduced. Vandenberghe et al. (2021) solved the scheduling problem by considering the emergency entry of patients on a regular schedule (Vandenberghe et al., 2021). Murça (2017) formulated a model and applied it to a case study of an airport in Brazil for optimal departure sequencing and operations scheduling with dynamic nature (Murça, 2017). Liang, Guo, and Fung (2015) developed a surgical treatment scheduling system that manages real-time modification in the operation room (Liang et al., 2015). Nguyen et al. (2014) applied Automatic Programming via Iterated Local Search algorithm to find out dispatching rules with the dynamic model environment in dynamic job shop scheduling (Nguyen et al., 2014).

5.1.3. Deterministic and Stochastic

In a deterministic model, certain assumptions are made with certainty. Though this model may have limited applications in practice, it is still useful to study basic concepts. Choi and Wilhelm (2020) studied an appointment method with deterministic entrance times and different exponential service times (Choi & Wilhelm, 2020). The goal was to reduce the customer-waiting and server-idle times. The work is more related to situations in which two or three clients are scheduled in each time slot. Glazer, Hassin, and Ravner (2018) considered a single-machine problem with a fine for deviance from the due date with the basics of job sizes being identical and deterministic (Glazer et al., 2018). In the stochastic model, uncertainty is known with explicit probability distributions. The uncertainty, which includes the random processing time, makes it difficult for the due date assignment. It is observed that in the literature, the stochastic model is mainly targeted at jobs and patients. Elyasi and Salmasi (2013) proposed the due date assignment and stochastic processing time of jobs in a single machine to curtail determining due dates and to reduce the overall cost of fined early and tardy jobs (Elyasi & Salmasi, 2013). Baker (2014) highlighted that problems with stochastic scheduling containing E/T have hardly been considered in the literature (Baker, 2014). He, therefore, studied the problem of how to reduce the overall E/T cost in a single-machine situation. A single machine using a stochastic situation with unequal E/T costs of jobs was reflected in the research paper of Lemos and Ronconi (Lemos & Ronconi, 2015). Wang, Liu, and Jin (2019) examined the capability of pre-emptive scheduling techniques using stochastic machine breakdown (Wang et al., 2019), processing time, and some other worsening conditions in the steel industry. In clinics or hospitals, patients visit doctors at random times, and hence, the stochastic model was studied by authors in this field. (Mancilla & Storer, 2012; Mancilla & Storer, 2013) proposed an algorithm for a stochastic nature of appointment sequencing/scheduling with waiting, idle, and overtime costs for a single-machine environment. They applied an algorithm for ordering surgical procedures for a doctor working in a parallel operating theatre with no certainty nature. Sun et al. (2021), Tsai, Yeh, and Kuo (2021), Jafarnia-Jahromi and Jain (2020) described the concept of stochastic scheduling surgery to tackle patients' arrival and patient appointment scheduling problem, respectively (Jafarnia-Jahromi & Jain, 2020; Sun et al., 2021; Tsai et al., 2021). Zhou and Yue (2021) and Zhou and Yue (2022) considered stochastic service times in multistage service systems to reduce the total costs of customers' waiting time (Zhou & Yue, 2021, 2022). Wu and Zhou (2022) considered the problem of scheduling and sequencing with stochastic service durations and client's arrivals (Wu & Zhou, 2022).

5.2 Classification of research papers on solution approaches used by authors

To obtain an optimum solution for objective functions, there are different methods that one could implement. Although many optimization algorithms could be used, there is not such a core one that is reflected to be the best for any case. The optimization approach which is appropriate for getting the solution to one problem may not be applicable to the other one, as it is subjected to various features. After review, some of the major solution approaches are identified and discussed below:

5.2.1. Optimization methods

The authors used integer models to optimize the objective function in scheduling and sequencing. Integer models are known by a variety of names, Mixed Integer Linear / Nonlinear Programming (MILP/MINLP) and Integer Linear Programming (ILP), according to the generality of the restrictions on their variables.

5.2.1.1. MILP and MINLP

Linear programming achieves the output of a linear objective function related to one or more constraints. In mixed integer programming, at least one variable should have an integer value. This approach is broadly used in the operations research area. MINLP is an optimization technique that handles nonlinear problems with continuous and integer variables. Bueno et al. (2020), Abdullah, Shamayleh, and Ndiaye (2019), Haoran et al. (2018), and Cafaro and Cerdá (2010) applied MILP. Pautasso, Cafaro, and Cerdá (2019) and Cerda, Pautasso, and Cafaro (2015) applied MILP as well as MINLP optimization techniques in their work for petroleum-based industries and demonstrated that the model yields an optimal schedule with low computational costs (Abdullah et al., 2019; Bueno et al., 2020; Cafaro & Cerdá, 2010; Cerdá et al., 2015; Haoran et al., 2018; Pautasso et al., 2019). Dang et al. (2021) proposed MILP and large neighbourhood search with a combined local search technique to determine a schedule to reduce the tardiness costs of demands and AGVs transportable cost within an industrial unit (Dang et al., 2021). Tsai et al. (2021) formulated MILP with rapid screening and stochastic approximation algorithms to tackle planning and sequencing decisions in a surgical scheduling problem (Tsai et al., 2021). Zhou and Yue (2022) articulated a stochastic program and utilized a sample average approximation approach to reframe this as a mixed-integer program as advanced (Zhou & Yue, 2022).

5.2.1.2. Dynamic Programming

Dynamic Programming (DP) optimization is a type of exact algorithm which guarantees to discover the optimal result for the problem. In this, the results of sub-problems are stored and reused so that re-computation is not required. The advantage of this optimization approach is to reduce time complexity from exponential to polynomial, but the larger the problem, the more complex the solution space and can make the algorithm slower. Liu, Lu, and Qi (2018) developed an optimal pseudo-polynomial time DP algorithm for rescheduling and for saving the overall cost of jobs in manufacturing (Liu et al., 2018), Mohan and Kumar (2016) adopted DP for solving the waste load scheduling problem (Mohan & Kumar, 2016), Lu, Liu, and Qi (2013) demonstrated DP algorithm to find the optimal price quotations and production scheduling in manufacturing (Lu et al., 2013), Chou, Lee, and Yeh (2013) analysed DP as a scheduling framework to determine the optimal development plan of a local water supply system (Chou et al., 2013).

5.2.1.3. Branch and Bound

Branch and Bound (BB) is another exact algorithm that helps to search for the optimal solution for combinatorial, discrete, and all-purpose algebraic optimization problems. In the BB algorithm, the procedure of dividing a large problem into more than one sub-problems is branching, and the procedure of computing a lower/upper bound for the optimum solution of a known sub-problem is bounding. The branch and cut method is a combinatorial optimization algorithm. This method uses both the BB approach and the cutting plane approach. In particular, this augments the formulation of the sub-problem with additional cuts in order to improve the bounds obtained from the linear programming relaxations. Lin and Chu (2013), Memmi and Laaroussi (2013), and Eun, Hwang, and Bang (2010) investigated the model using BB algorithm with constraints like production lines (Eun et al., 2010; Lin & Chu, 2013; Memmi & Laaroussi, 2013), labour, warehouse capacity, time period for production, order fulfilment rate, resource precedence and job sequence to curtail the overall cost in the manufacturing industry. Baker (2014) studied this algorithm to find optimal solutions to minimize complete expected earliness and tardiness costs (Baker, 2014). Martínez et al. (2019) used branch and check to find the best solutions to the production planning problem of the packaging industry (Martínez et al., 2019). Canca et al. (2019) applied a model with a branch and cut in the town of Seville (Spain) for constructing a metro network (Canca et al., 2019).

5.2.2. Heuristic, Metaheuristic, and Hyper-heuristic

Heuristic defines a computational method that finds an optimal result through repetition to develop a candidate result with respect to a given measure of quality but doesn't assure optimality. It is noticed that many stand-alone and hybrid heuristics are present to address scheduling and sequencing problems to achieve objective function. Some are deliberated for a particular application, and others are aimed at general applications and referred to as meta-heuristics. The integration of the machine learning approach, the practice of selecting, combining, generating, or adapting different simple heuristics to solve problems, is referred to as hyper-heuristics. Cayo and Onal (2020) applied a heuristic approach for sequencing production orders and aimed to reduce overall tardiness with setup time (Cayo & Onal, 2020). Ardakani, Fei, and Beldar (2020) presented that a heuristic algorithm works better than the mathematical model for the truck to door sequencing (Ardakani et al., 2020). Zhou, Yang, and Zheng (2018) used it in flexible job shop scheduling for the assignment of machines and sequencing rules of jobs (Zhou et al., 2018). Lemos and Ronconi (2015) determined the job sequence and the due dates, which reduce the probable E/T costs by applying a heuristic approach (Lemos & Ronconi, 2015). Li et al. (2014) used a hyper-heuristic approach in cellular manufacturing systems for scheduling inter-cell.

5.2.2.1. Genetic Algorithm

Genetic Algorithm (GA) is built on the Darwinian principle, of "survival of the fittest". GA is a random-based classical evolutionary algorithm (Li et al., 2014). In GA, a list of promising solutions is generated at each phase, and reiteration generates an improved solution by searching a special neighbourhood. It merges two existing sequences, choosing some features from one and the remaining from the other. The new candidates are observed as descendants of the present, and thus the term is taken from evolution and genetics. The GA algorithm typically ends with a given number of reiterations, but other discontinuing rules can be forced. The best-performing sequence in the last reiteration is taken as the solution.

(Shen et al., 2021) considered unrelated parallel machines in the pasta manufacturing industry’s flexible job shop scheduling problem and applied GA to handle the sequencing of the job with machine allocation. They illustrated that the proposed algorithm outperforms with the reduction in makespan, energy cost and labour cost. Bayu et al. (2020) developed a model using GA including a discrete-time for sequencing the operations in gasoline blending (Bayu et al., 2020). Kurniawan et al. (2020), Zhou et al. (2018), and Su et al. (2015) executed GA approach in manufacturing company, and optimum scheduling was realized through it, considering the specific costs and value inputs from broad task cost modelling (Kurniawan et al., 2020; Su et al., 2015; Zhou et al., 2018). Toledo et al. (2014) showed that the GA programming approach performs better concerning production costs and run times when implemented considering the case study of a soft drink company (Toledo et al., 2014). Costa, Fichera, and Cappadonna (2013) tested to evaluate the impact of the workers' skills on both manpower cost and makespan (Costa et al., 2013). From research, it is noticed that GA outperforms not only in manufacturing but also in other industries like warehouse, railway, education, textile, and transport.

5.2.2.2. Discrete Differential Evolution

In the Discrete Differential Evolution (DDE) algorithm, initially, the target population gets altered to yield the new population. Later the target population remerges with the new population to yield an experimental population. Lastly, a selection operator is used to both target and experimental populations to decide who will be there for the succeeding generation depending on fitness evaluations. In the DDE algorithm, the construction and destruction process is used as an operator to yield a new population. Nonsiri, Christophe, and Mokammel (2014) optimized sequencing of engineering tasks with the use of DDE algorithm (Nonsiri et al., 2014).

5.2.2.3. Ant Colony Optimization

Ant Colony Optimization (ACO) is used to find near-optimum results for challenging optimization problems. It is one of the metaheuristic approaches to optimization. Here, artificial ants as agents find near-optimal results. The problem is altered to search for a better path on a weighted graph. The agents (ants) move on the graph gradually to yield better results. Here, the finding of the near-optimal solution is a stochastic approach and depends on a model of pheromone. The pheromone model has a list of factors related to either edges or nodes of the graph for which values are altered at run-time by agents. Shobaki et al. (2022) described an ACO algorithm to schedule register pressure-aware instructions (Shobaki et al., 2022). Nazif (2018), Haoran et al. (2018), and Li et al. (2014) provided an ACO algorithm that helps in the sequencing of jobs and allotting resources at the same time (Haoran et al., 2018; Li et al., 2014; Nazif, 2018). Fernandez et al. (2014) implemented ACO for interpreting the scheduling rules in a galvanizing line and showed that a good solution could be obtained in a bit of calculation time (Fernandez et al., 2014). Xianru (2012) used ACO to reduce the overall delay cost by finding the aircraft's sequencing and landing times schedule (Xianru, 2012).

5.2.2.4. Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a random search approach. In PSO, the animal activities of the individuals in the swarm get copied as a searching technique. The PSO notion was initiated from the behaviour of bees' swarm, birds flocking, or fish schooling. The PSO result is denoted as a particle, while the group of results is known as a particle swarm. For every particle, there are two key features, velocity and position. The particle acquires logical understanding from its experiences and societal understanding from the swarm to help the particle for getting a better position; with the help of a new velocity, a particle shifts to a different location. The better position of every particle and also the position of the swarm of particles is altered if necessary. Accordingly, the velocity of the particle is then modified depending on the particle's experiences (Wisittipanich & Hengmeechai, 2017). PSO has been successfully applied by (Fang & Lin, 2013; Wang et al., 2018). The study described that PSO could resolve the operating room scheduling efficiently and effectively, and optimize the jobs allocation and jobs sequencing to help in reducing overall completion time and reduction in cost incurred for raw materials. It was also applied to reduce the overall tardiness and power cost by finding the optimal sequence of jobs.

5.2.2.5. Tabu Search

Tabu Search (TS) is a combinatorial approach of optimization and search techniques built on getting the better existing neighbourhood solution point. It finds the better point of search space concerning the objective function, although it may not be as good as the present solution point. If some tabu motions result in better solutions, these tabu statuses are acknowledged, according to an aim. The TS technique is a search methodology with a flexible memory arrangement, and various problems can be solved (Mobaieen et al., 2012). TS, a metaheuristic algorithm, was studied by (Rezaeiahari & Khasawneh, 2020) to find a near-optimal solution for scheduling medical tourists'.

5.2.2.6. Simulated Annealing

Simulated Annealing (SA) is a mathematical meta-heuristic approach with a stochastic feature. The concept of SA is based on the simulation of thermal annealing of critically heated solids. In SA, initially, the search space examines original results and yields a new one through alteration. The cost of a new result which is acquired after alteration is calculated. If the objective function's value is improved than the current value of the objective function, then the altered solution is accepted, or else it is accepted according to the threshold probability. Mendonça et al. (2022) used SA and discovered that it is an efficient strategy for solving silviculture optimization problems in a short amount of period (Mendonça et al., 2022). Singh, Cheng, and Anumba (2021) used SA to optimize the schedule for pipe installation in the piping project to reduce the cost and length of project time (Singh et al., 2021). Rezaeiahari and Khasawneh (2020) used SA with TS for scheduling health visitors who travel to targeted health centres to reduce the flow time of visitors (Rezaeiahari & Khasawneh, 2020). SA with GA was used for the sequencing of several courses related to the classroom in education by Czibula et al (Czibula et al., 2016). Areal, Martin, and Campos (2011) applied SA and GA in the automobile industry to get the optimum sequence for car assembly lines to utilize the workforce and resources efficiently (Areal et al., 2011).

5.2.2.7. Crow Search Algorithm

Crow Search Algorithm (CSA) is a metaheuristic algorithm dependent on the intelligent behaviour of a crow. Even though CSA is nature motivated, it has prime peculiarities from a few accepted algorithms such as PSO, GA, or Heuristic Search. There are only two considerations in CSA, flight length and awareness probability, which should modify. Reddy et al. (2022) used the CSA to resolve the problem of scheduling tasks and tools in a multi-machine flexible manufacturing environment, and they demonstrated that the CSA delivers better solutions to reduce makespan (Reddy et al., 2022).

5.2.2.8. Search Algorithms

Authors used different search algorithms for optimization such as Variable Neighbourhood Search (Yan et al., 2014), Iterated Reference Greedy algorithm (Pei et al., 2019), Multi-Start Iterative Search heuristic (Czibula et al., 2016), Greedy Randomized Adaptive Search Procedure Heath, Bard, and Morrice (Heath et al., 2013), Automatic Programming via Iterated Local Search-APRILS Nguyen et al. (Nguyen et al., 2014), Stochastic mixed integer programming based local search (Santos & Almada-Lobo, 2012), Scatter Search (Gholipour-Kanani et al., 2011), and Backward Search algorithm (Supithak et al., 2010).

5.2.2.9. Fuzzy Approach

If enough information is not present with respect to objective functions and there is not essential certainty about the significance of objectives, then the problem may be expressed as a fuzzy goal programming problem, for example, aircraft landing time. Haoran et al. (2018) proposed a self-learning approach by merging fuzzy analysis and ACO to acquire complete optimum scheduling of a multi-product pipeline (Haoran et al., 2018). Tavakkoli- Moghaddam, Yaghoubi-Panah, and Radmehr (2012) mentioned that if complete data is not present, then one can use a fuzzy approach (Tavakkoli-Moghaddam et al., 2012).

5.3. Classification of research papers based on industries.

To conduct any research, industrial applications perform an important role. Due to extensive growth and competition in the industry, the research should have improved quality. The research papers that appeared in the literature search have applications of CSS in several industrial zones. CSS application in the Manufacturing zone appears in large amounts (45%) following this Service (37%), and Health (18%). The most important industries found in research that have concentrated on CSS are shown in Figure 2. Research papers on CSS are mainly found in the Manufacturing Sector with a large number (54) following this the health industry (35), Information Technology (IT) industry (16), Transport (13) and Airport (10) sectors. The researchers and practitioners worked in several types of industries like Automobiles, Construction,

Construction Machinery, Cement, Door Lock Manufacturing, Education, Electrical and Electronics, Energy Manufacturing, Food, Logistics, Mining, Packaging, Painting, Petrochemical, Plywood, Process, Pulp and Paper Mill, Ship, Soap, Steel, Supermarket, Textile, Water and Waste Management. Out of the 281 papers studied, there were 82 research papers where no specific industrial sector information was mentioned.

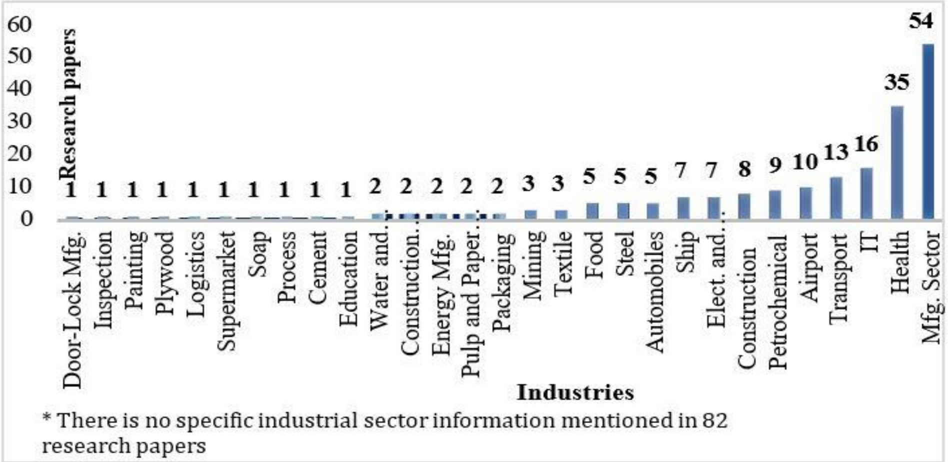


Figure 2. Research papers based on focused industries.

CSS work done in the manufacturing sector contributes the maximum amount of research papers, followed by service and health sectors. From the literature, it is found that generally, manufacturing industries focused on sequencing of jobs to schedule on machines (Álvarez-Gil et al., 2022; Cayo & Onal, 2020; Kurniawan et al., 2020; Pei et al., 2019). Apart from general manufacturing industries, researchers worked in specific industries like steel, food, textile, pulp and paper, vehicle, electronics, education, airport, and ship port. Health industries mainly stressed sequencing of patients or surgeries to schedule in operation rooms. Service industries that include transportation or logistics concentrated on sequencing trucks, aircraft, ships, pipelines and packaging lines. In the computer or IT branch, the CSS is mainly focused on sequencing tasks on servers with the allocation of resources. In the project management area, the researchers mostly studied sequencing activities/elements to minimize the cost. The research papers studied in the literature highlighted case studies and also involved model development using algorithms, structures, and practices in industries.

5.4. Classification of research papers based on publishers and journals.

The journals from different areas such as production/industrial engineering, management, logistics, transportation, information systems/technology, optimization, applications, statistics, and healthcare disciplines published research work based on scheduling and sequencing with cost as the primary aim. Among the leading journals, Computers and Industrial Engineering (7.4%), Computers and Operations Research (4.9%), and the International Journal of Production Research (4.2%) have the most significant number of articles considerably. This may be due to the vast developments in the computer field in recent years and their involvement in industries and optimization techniques. These journals mainly focus on developing new computerized methods for resolving industrial engineering issues and their applications. European Journal of Operational Research, which primarily focuses on innovative applications of operational research, and Industrial and Engineering Chemistry Research, which deals with research in applied chemistry and chemical and bimolecular/biochemical engineering, holds the fourth and fifth position respectively (3.5% and 2.4%). IIE Transactions (2.1%) have the sixth position. IEEE Access mainly focuses on research or development across all electrical and electronics engineering fields, including multidisciplinary applications, International Journal of Production Economics, which covers the topics treating the interface between engineering and management, and the Journal of Scheduling which broadly covers the techniques and applications of scheduling, are in the seventh position (1.8%). Applied Mathematical Modelling deals with the mathematical modelling of engineering and environmental processes, and industrial and manufacturing systems. Computers and Chemical Engineering highlights the new growth in the application of computers and systems technology to engineering issues related to chemical industries. Expert Systems with Applications deals with intelligent systems. Production and Operations Management, and Production Engineering cover the latest research in industrial and production engineering. The journals mentioned above are in eighth place (1.4% each). Other journals with around 1% papers are not mentioned due to space limitations.

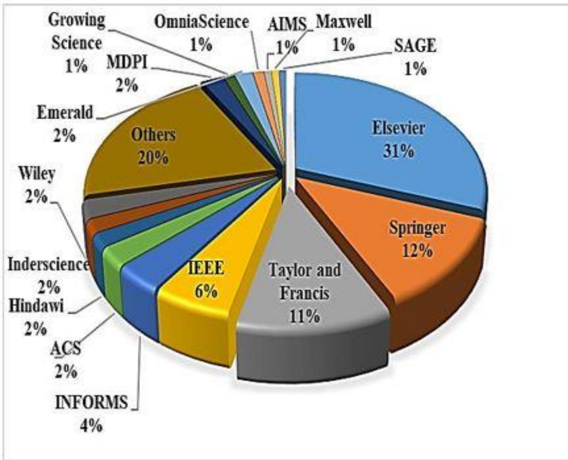
Considering the publishers, Elsevier contributed the most number of research papers (31%) on scheduling and sequencing with cost as the main aim, followed by Springer (12%), Taylor and Francis (11%), Institute of Electrical and Electronics Engineers Inc. (IEEE 6%), Institute for Operations Research and the Management Sciences (INFORMS 4%), American Chemical Industry (ACS 2%), Hindawi (2%), Inderscience (2%), Wiley (2%), Growing Science (1%), MDPI (2%), Emerald (2%), American Institute of Mathematical Sciences (AIMS 1%), Maxwell (1%), SAGE (1%). Other publishers contributed 20% altogether to the research. The literature study from the above-stated publishers shows diverse research in work. Figure 3 presents the classification of research papers with publishers' details.

5.5. Classification of research papers based on year of publication.

Figure 4 shows the classification of CSS research papers published from 2010 to 2022. The researchers mostly applied mathematical computations till the initial years of the 21st century. Still, later researchers felt to have easy and quick solutions due to the exponential growth of industries which can be achieved by applying the advanced computational algorithm in the CSS field, especially in the last few years.

5.6. Dynamic authors in CSS research

Authors who are actively involved and participated in the recent publication of the research papers are identified in this study. Overall, 832 authors contributed to 281 research papers on CSS work. All the authors, that is main author as well as co-author/s, are considered from 281 research papers. A. Al-Refaie with five articles, S. Zhou with four articles and D. C. Cafaro, Y. Dong, X. Li, R. Morabito, J. Cerdá, Z. Gao, L. Magatão, A. Al-Hawadi, M. Elhoseny, and Q. Yue with three articles each, seems to be the most contributing authors in terms of publishing the research work (Al-Refaie et al., 2018; Bueno et al., 2020; Cerdá et al., 2015; Gao et al., 2015; Gao et al., 2021; Lakhan, Memon, et al., 2022; Martínez et al., 2019; Martinez et al., 2018; Wu & Zhou, 2022; Yan et al., 2014; Zhou & Yue, 2021). While the rest, 820 authors who published one or two research papers, are not mentioned due to space constraints. Fang and Lin (2013) in Manufacturing, Al-Refaie, Judeh, and Chen (2018), Gul et al. (2011) in Health, and Mak, Rong, and Zhang (2015) in appointment scheduling are the authors whose work received more than 100 citations till now as shown by the publishers (Al-Refaie et al., 2018; Fang & Lin, 2013; Gul et al., 2011; Mak et al., 2015).



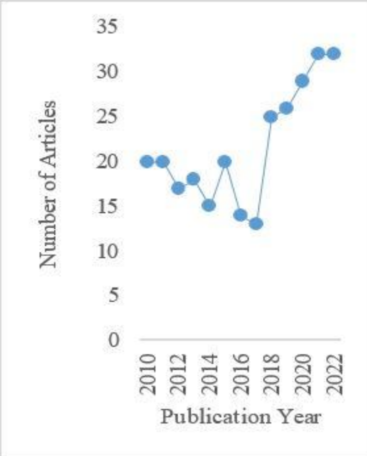


Figure 3. Publishers Figure 4. Year of publication

5.7. Classification of research papers based on countries.

41 major countries worldwide have done literature on the findings on Scheduling and Sequencing with cost as the primary aim. When the country of the first author is considered, out of 281 research papers, China and United States have done the most research in terms of research papers. Apart from these two countries, other countries like Iran, India, Brazil, Spain, Germany, Netherlands, Canada, Italy and Taiwan, have also made a significant contribution to the number of publications. The countries like Bangladesh, Egypt, Finland, Indonesia, Malaysia, Poland, Portugal, Saudi Arabia, Singapore, Slovakia, South Africa, and the United Arab Emirates are the places where the number of publications is somewhat less in number. This shows that there are plenty of opportunities in these nations to research and further develop the area mentioned above. China and the USA collectively contributed around 36% of the total research in this area. Most of the researchers from China focused on the manufacturing industry. On the other hand, United States research appears mostly in health, and authors concentrated on sequencing and scheduling of patient's appointments, and surgeries in operating rooms. The review reports that authors from the United States targeted this area recently more in numbers.

5.8. Classification of research papers based on various constraints.

A scheduling constraint is a restriction placed on a schedule that affects the start or finish period of activity. Scheduling problems have constraints exclusive to the particular industry. Scheduling methods must be highly tailored to handle the constraints. These constraints can be in the form of cost, quality, customer satisfaction, time and resources. In finding the near-optimal solution in scheduling and sequencing, there can be hard constraints and soft constraints. A hard constraint is a constraint that must be fulfilled by some practical resolution to the model. Instead, a soft constraint can be disrupted, but disrupting the constraint acquires a fine in the objective function. Table 1 shows various possible constraints in different industrial sectors focused on by the authors.

Table 1. Constraints in different industrial sectors

Constraints	Description
	Industrial Sector/ Industry: Airport
Capacity	(Rodríguez-Sanz et al., 2021) considered constraints on the number of arrival and departures at the airport, which results in delays with a significant effect on costs for air companies and travelers.
Time, ordering, safety, en-route	(Stiverson & Rathinam, 2011) elaborated on the management of aircraft on the runway concerning time ordering and safety constraints.
Situational and operational	(Eun et al., 2010) suggested different sets of delay times, types of aircraft and approaching route constraints.
Runway separations	(De Maere et al., 2018) discussed the different constraints like separations of the runway, hard time window and take-off /landing deadlines. In addition, the authors noted that the constraints assuming departures are complex as compared to arrival.
	Industrial Sector/ Industry: Automobiles
Resource, precedence	(Areal et al., 2011) addressed that car sequencing is a resource- constrained scheduling problem and needs to preserve order while moving through the assembly line.
	Industrial Sector/ Industry: Cement Manufacturing
Quality	(Asad, 2011) suggested that the raw material (Limestone) must contain the required percentage of chemical elements.
	Industrial Sector/ Industry: Computer/ Information Technology
Deadline	(Lakhan, Mohammed, et al., 2022) addressed that completing the internet of things application in a certain time period or earliest completion time helps achieve deadlines.
Resource	(Kim et al., 2012) discussed the limit to the assignment of computing elements to datasets.
	Industrial Sector/ Industry: Construction
Resource	To achieve optimization, (Yuan et al., 2021) considered time- resource constraints and attempted to diminish the effect of the activity execution period on the total task.
Safety	(Shams Abadi et al., 2021) addressed the resident's safety constraints in case of fire conditions at the renovation construction site.
	Industrial Sector/ Industry: Electronics
Time	(Cui et al., 2019) addressed the timeliness constraints to find the optimum highest temperature and variant in temperature.
	Industrial Sector/ Industry: Flow Shop
Block	(X. Zhang et al., 2019) proposed a concept to find the best solution in the scheduling with a limited block or buffer in the flow shop of each factory in a scattered manufacturing situation.
Planned production	(Ramezanian & Saidi-Mehrabad, 2012) addressed constraints such as precedence, resource, the capability of the work centre, time and the relationship between inventory, production plan and customer demand.
Job sequence	(Paul & Azeem, 2010) pointed out that the sequence of jobs on the machine should be the same for all the machines.
	Industrial Sector/ Industry: General
Precedence constraint	(Said et al., 2021) addressed that the lower-level task should be optimal, then only the upper level can achieve the near-optimal solution.
Precedence	(Wisittipanich & Hengmeechai, 2017) suggested that precedence constraint is vital to achieve the goal in industries
Precedence, resource, time	(Werner et al., 2018)discussed batch production situation constraints, precedence constraints, resource constraints, and time for operation arrangement or costs.
	Industrial Sector/ Industry: Health
Security	(Lakhan, Mohammed, et al., 2022) mentioned the security of data as a constraint and proposed blockchain-enabled internet of medical things to address it.
Resource	(Nazif, 2018) considered arrangements in the operating room, surgery time, and recovery time of patients as constraints.

Industrial Sector/ Industry: Job Shop	
Capacity	(Rohaninejad et al., 2015) addressed that capability of each machine is limited in flexible job shop scheduling.
Stock level	(Álvarez-Gil et al., 2022) mentioned the stock levels at the galvanizing line as constraints
Industrial Sector/ Industry: Manufacturing	
Machine interference	(Kobayashi, 2021) considered that only one item could be set up or handled in a single period, and there should not be any machine interference.
Shelf-life	(Wang et al., 2018) focused on optimizing the job allocation and sequencing to reduce overall completion time and cost considering the shelf life of raw materials.
Precedence	(Su et al., 2015) mentioned operations should fulfil precedence constraints. The precedence constraint is represented by the precedence graph of operations.
Innate constraints of the production	(Le & Pang, 2013) discussed constraints like the due date of part type, precedence constraints, resource allocation constraints, and non-pre-emption constraints.
Production line constraints	(Lin & Chu, 2013) tackled the constraints like a production line, labour, warehouse capability and order fulfilment in a given time by articulating a model with integer programming.
Industrial Sector/ Industry: Mining	
Accessibility/ precedence	(Armstrong & Galli, 2012) discussed accessible blocks to be mined, limiting the amount to be mined, and limiting the duration of extraction as constraints.
Industrial Sector/ Industry: Oil	
Volume and flow rate constraints	(Quinteros et al., 2019) studied the volume and flow rate constraints of products in the pipeline and used a computerised model for planning and scheduling operations.
Carryover setup	(Abdullah et al., 2019) described the supplier, warehouse, a customer with affiliate constraints associated with the product.
Industrial Sector/ Industry: Pulp	
Synchronizatio n	(Martinez et al., 2018) addressed different constraints like the availability of a number of molds, the capacity of machines and the synchronization of steps in product manufacturing.
Industrial Sector/ Industry: Railway	
Movement of the train, speed restriction	(Y. Zhang et al., 2019) highlighted that after the maintenance of the track, speed restriction constraint should be considered for the first two trains active on the way instead, a speed reduction of the operational train is modelled while the reverse route is under maintenance.
Industrial Sector/ Industry: Robot Project	
Cost, time, quality	(Nonsiri et al., 2014) mentioned that to overcome constraints related to cost, time and quality of product, the formation of a suitable schedule of tasks is prominent in the engineering process.
Channels	(Corry & Bierwirth, 2019) presented shipping channels as a constraint due to less space to pass two opposite ships and depth constraints because of tide cycles in water.
Industrial Sector/ Industry: Steel	
Technical constraints	(Fernandez et al., 2014) focused on technical constraints, including jobs' release date, operations sequence in the job, waiting time, and volume of machines on which operation is performed.
Industrial Sector/ Industry: Transportation	
Flowrate lower limit	(Haoran et al., 2018) modelled injection, delivery constraint, time and pipeline conditions constraints using MILP.
Time window	(Vahdani, 2019) considered the time window for the arrival and departure of trucks by assigning the doors after arriving at cross- dock according to their arrival sequence.
Industrial Sector/ Industry: Transport (Chemical And Fuel)	
Product sequencing	(Gifford et al., 2018) described the product sequencing constraints for the transportation of chemicals and fuels due to the supply characteristics.

5.9. Uncertainty studied in CSS.

Uncertainty is an erratic event that interrupts the process of the completion of a task. It can be controlled by reducing the degree of uncertainty and its impact on the process by making a survey of tendencies related to the process used in various industrial sectors to predict demand and create explicit specifications of customers' requirements. In uncertainty, researches primarily comprise stochastic scheduling, robust scheduling and fuzzy scheduling. The probability distributions approach is used in the representation of stochastic scheduling. Robust scheduling is an amount of the flexible target of the scheduling considering uncertain parameters and unpredicted events. The fuzzy logic methodology is used to represent fuzzy scheduling to define the uncertainties with the satisfaction of constraints.

The concept of uncertainty is applicable in all fields, however, researchers mainly highlighted its importance in the health sector. According to Pang et al. (2022), scheduling MRI jobs entails uncertainties such as patient arrival, scanning time, and preparation time (Pang et al., 2022). Rezaeiahari and Khasawneh (2020) considered the treatment duration of patients as uncertain and presented a simulation-optimization method for scheduling the patients who visited the medical centre over multiple days (Rezaeiahari & Khasawneh, 2020). Mandelbaum et al. (2020) highlighted that patients' punctuality and service durations are uncertain and bring out a data-driven (Mandelbaum et al., 2020), robust approach to handle the uncertainty. Nazif (2018) observed that the time required for surgery is uncertain, the author represented the uncertainty of time with fuzzy numbers (Nazif, 2018). Saadouli et al. (2015) stated that optimizing the allocation of surgeries to operating rooms in orthopaedics medical centres is difficult due to uncertainty in the duration of surgery and recovery of patients (Saadouli et al., 2015). They applied lognormal probability distributions to generate time and handled the uncertainty to achieve the near-optimal solution. Gul et al. (2011) addressed the complications in scheduling Outpatient Procedure Center activities as it depends on uncertain parameters like surgery duration (Gul et al., 2011).

In manufacturing, Purohit and Kumar Lad (2016) considered uncertainties regarding raw material quality, error in demand forecast, and machine production and handled these uncertainties parameters with a probability distribution approach (Purohit & Kumar Lad, 2016). Lu et al. (2013) focused on customer order placement which is uncertain as a client may order inquiries to several suppliers and give the order to only one of them (Lu et al., 2013). This uncertainty in order placement is represented by the probability function to reduce its impact. Le and Pang (2013) studied dynamic scheduling with power consumption uncertainties, formulated these uncertainties using the probability distribution function and found a way to reduce the effect of uncertainties (Le & Pang, 2013). Paul and Azeem (2010) represented the uncertainties in the flow shop scheduling problem and handled them using fuzzy sets and logic (Paul & Azeem, 2010).

Apart from health and manufacturing, uncertainty was also highlighted by authors in other areas. Yuan et al. (2021) formulated the model with the representation of uncertain execution time of activity in terms of fuzzy sets which helped in reducing the effect of uncertainty on the execution period of the task in the project (Yuan et al., 2021). Rodríguez- Sanz et al. (2021) proposed a model which manages runway usage by sequencing aircraft operations by minimizing delays (Rodríguez-Sanz et al., 2021). They presented a robust model of scheduling optimization by considering uncertainties in tactical working steps of aircraft operations. Murça (2017) considered that taxi-out time is uncertain in nature, applied a robust approach for finding optimal solutions and showed optimistic results against uncertainty which helped in the reduction of delay in the taxi-out time of the airport (Murça, 2017).

5.10. Computational time

Computational time is an important parameter in the industry for task scheduling and sequencing problems. The length of time necessary to complete a computation process is computational time. With cost parameters, computational time is also important. Researchers can find the best solution for small instances in a fraction of the time, but finding the best solution for large-scale instances is more difficult. Some articles emphasised reducing computational time, but just a handful expressed it in terms of figures. Tsai et al. (2021) adapted a stochastic optimization model for a surgical scheduling problem (Tsai et al., 2021). The experimental results demonstrated that the suggested algorithms obtain a nearly optimal schedule in reasonable computational time. Martínez et al. (2019) used an exact optimization technique in the packaging sector and found that a solution to the problem may be found 10.9-97 times faster than usual computational times (Martínez et al., 2019). Abdullah et al. (2019) investigated a demand planning problem in the petrochemical sector and compared solutions in terms of computational time. They discovered a heuristic that can tackle large instance problems in less amount of time than traditional techniques providing high-quality solutions (Abdullah et al., 2019).

Fernandez et al. (2014) used ACO to schedule a galvanising line at a steel mill and discovered that it produces a solution in a short calculation time (Fernandez et al., 2014). Asad (2011) applied a blend of a heuristic sequencing algorithm and a MILP-based blending formulation to ensure that raw materials for the cement manufacturing activity were always available (Asad, 2011). He compared the heuristic model to manual scheduling and discovered that the heuristic model contributed to substantial time savings in the solution generation process. Eun et al. (2010) introduced a Lagrangian dual decomposition approach, noting that the computation time can be greatly lowered, especially in congested airspace (Eun et al., 2010).

5.11 Programming languages and optimization software packages

The algorithm to produce an optimal solution for objective functions is formulated using a variety of programming languages and optimization software packages. After review, software packages like CPLEX (Simplex algorithm and developed in C), General Algebraic Modeling System (GAMS), MATrix LABoratory (MATLAB), Lingo are identified which are used by the authors. The authors coded the algorithm in Python, Java, C++, Visual Basic (VB), and VB.Net in order to produce the best result for objective functions. It has been noted that Python has become increasingly popular recently for the development of optimization systems.

6. The gist of cost reduction estimation in CSS by authors

Authors in the field of CSS showed that the optimization model helped in saving the cost and the computational time required to complete the activities in scheduling and sequencing. The notable papers are discussed in this section. Laili et al. (2022) used the internet of things environment to minimize the cost of the order with many jobs (Laili et al., 2022), which they accomplished by applying local search algorithms and saved 5.6 to 11.8 per cent on rental costs. Dang et al. (2021) illustrated the effectiveness of the combinatorial approach of local search with neighbourhood search to reduce the travel cost of automated guided vehicles within a plant by 20%-50% (Dang et al., 2021). Shen et al. (2021) applied a GA to actual-world data of the pasta industry and achieved a reduction in makespan (Shen et al., 2021), energy cost and labour cost by 8.50%, 5.24% and 6.02%, respectively. Singh et al. (2021) applied a 3D and 4D building information modelling approach in multiple pipe system installation projects for capturing important information (Singh et al., 2021). The time period required for planning, sequencing and scheduling in this project was reduced by 96%-97%. Rijal et al. (2021) demonstrated a case-study of the supermarket chain in Netherlands (Rijal et al., 2021). They showed that the metaheuristics approach for allotting and sequencing orders to ordering pickers effectively reduces computation time by 80%. Gao et al. (2021) applied MILP to find an optimal solution for sequencing ship problems for the transportation of raw material at a steel plant which effectively helped in the reduction of 20 million Chinese yuan renminbi (CNY) per year (Gao et al., 2021). Mandelbaum et al. (2020) applied a data-driven robust approach for optimization by considering appointment scheduling and sequencing on a dataset of the cancer centre (Mandelbaum et al., 2020). As a result, they could reduce overtime and waiting time costs by 15%-40% uniformly. Quinteros et al. (2019) developed a computerized model by applying an integer programming approach for an oil company where oil product sequencing is required and showed that the operating cost could be saved by 10% (Quinteros et al., 2019). Gao et al. (2015) suggested the assignment of tools to machine, optimal sequencing of lots to machine, and changeover of the machine, a three- stage technique for semiconductor devices (Gao et al., 2015). They were found to be effective in the reduction of costs by 62%. Memmi and Laaroussi (2013) applied a branch and bound algorithm for deciding optimum products sequencing and estimated the start-up plus setup cost over a period and attained to curtail overall manufacturing cost by 30% (Memmi & Laaroussi, 2013). Heath et al. (2013) presented a scheduling and sequencing model for the electronics industry by applying a heuristic approach that helped in cost savings and 17-18% improvement (Heath et al., 2013).

7. Conclusions

The review's goal is to bring attention to CSS ideas. The review consists of research papers from the years 2010-2022. The term "scheduling and sequencing" is searched in the research paper's title, abstract and keywords of the Scopus database. The research mainly focuses on cost minimization as the primary aim, and hence the word "Cost" is searched in the abstract of these papers. According to this, 281 research papers are found, and the data is collected considering different parameters; later, these papers are studied and organized. All papers are distributed to the important groups based on their applications. This literature review deliberated the report of CSS based on scheduling models, algorithms applied, and research sectors, constraints and uncertainties. The basic judgement of the review shows that more research is done using a simple integer model. Most progressive algorithms are being used for the exploration of real-world problems. High-configuration computers can help reduce computational time, but in reality, the model normally runs on desktop computers with basic configuration in some industrial units. The solo optimization technique is observed to be insufficient to find optimal solutions; thus, the authors used a hybrid approach. The optimization model helped in saving cost and also the computational time required to complete the activities in scheduling and sequencing. The resource precedence, capacity, technical and time constraints in CSS can be prevented by analysing the past data of related plants. It is seen that the uncertainty in health, manufacturing, service and project management described by researchers can be handled by a probability distribution and fuzzy logic approach. This study is one of the precise analyses that systematically details the CSS and adds the general literature review. This study will help improve the understanding of the present state of work in the scheduling and sequencing field. Even though a sufficient amount of research work is presented on CSS in journals considered in this review, the concept of CSS still has opportunities for future development. The significant findings, gaps, and future research directions in the field of CSS is discussed in detail as follows.

7.1. Significant findings

- Single-machine models are studied more as compared to multi-machine models. Static and deterministic models being the basic ones are still being studied, but considering the realistic nature, the shift can be seen more towards dynamic and stochastic models during recent years.
- Most of the work is done using an integer linear programming model, while few give the theoretical concepts of CSS. Various algorithms based on heuristic and metaheuristic approaches are used for finding optimal solutions. Some authors also used a combinatorial approach to find a near-optimal solution.
- In research papers, CSS application is found in almost all industrial sectors, the Manufacturing domain has a maximum share (45%), followed by Service (37%) and Health (18%),
- More CSS work can be seen in manufacturing as its original base, but at the same time, it is observed that the health and service zones have also contributed to the literature. Authors presented their work on CSS using different case studies in computer/IT, airport, project management, painting, textile, steel, medical industries, construction project, food, vehicle, education, pulp and paper, ship port, and soap.
- The topic of scheduling and sequencing has been studied since the middle of the nineteenth century. Still, CSS literature has made significant contributions since the year 2018 by applying different algorithms and models.
- Most of the research in CSS comes up in two countries China and the USA; together, they hold 36% of the study.
- A. Al-Refaie with five articles, S. Zhou with four articles and D.C. Cafaro, Y. Dong, X. Li, R. Morabito, J. Cerdá, Z. Gao, L. Magatão, A. Al-Hawadi, M. Elhoseny, and Q. Yue with three articles each, seems to be the most contributing authors in publishing the research work on CSS.

7.2. Gaps identified

- A large number of research papers explained the integer model, but methods such as simulation for the support have been used in a very small number of articles.
- Very few papers discussed the combinatorial approach of different optimization algorithms.
- Even though many research papers are presented on the CSS concept in the manufacturing background, these papers fail to show a systematized model for improving real-world situations in manufacturing.
- Mathematical and structural equation modelling is put forward in research papers, but automatic programming in an innovative way for the industry is required to get quick output.
- Research shows that the maximum work is done in a single-machine environment, but research on multiple machines is limited, and usually used in industries.

7.3. Limitations

- This study is limited in reviewing those articles which contain the term "scheduling and sequencing" in the title, abstract and keywords of the article and then the term "cost" in the abstract of these papers. Chances are there that there may be studies, which might not have included the phrase "scheduling and sequencing" in the title, abstract and keywords as well as "cost" in the abstract, even though it concentrates on the CSS as the essential background.
- A few articles from the 281 articles considered in this study which have the term 'cost' in their abstract may have other objective functions as the main goal instead of cost.
- In order to keep the study's focus narrow, only journal articles are taken into account; conference papers, brief surveys, book chapters, and conference reviews are not included.
- Only articles written in English are taken into account; the analysis excludes 27 articles written in other languages.
- This research covers publishers from the Scopus database like Elsevier, Springer, Taylor and Francis, IEEE, INFORMS, ACS, Hindawi, Inderscience, Wiley, Emerald, MDPI, and Maxwell. It gathers a wide range of technical studies published in several reputed journals. All the determinations have been taken in, including the several parameters and bases for the judgement of articles. Still, in the future extensive study can be done to deliver clearer insight into CSS.

7.4. Future research directions

- Literature on CSS is examined, and it is revealed that the research started with the use of the integer model and moved towards developing the algorithm for optimizing scheduling and sequencing. Future research in the CSS area requires the combinatorial approach of different computational models. With this computational, algorithmic model, and the automatic programming approach is also needed to optimize the scheduling and sequencing area.
- The number of research papers provides a sense of the industries where the most work has been done and the regions where the same might be explored. As an alternative, researchers can focus on fields where no research has been done in this area.
- There are many criteria such as completion time, flow time, lateness, late or tardy jobs, tardiness, earliness, early jobs, the cost of optimizing scheduling, and sequencing discipline but researchers focused on one or two criteria at a time. According to a real situation, there is a need to consider the criteria simultaneously, which may be complex but can be achieved with cutting-edge technology or a multidisciplinary approach.

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