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COST FACTOR FOCUSED SCHEDULING AND SEQUENCING: A NEOTERIC LITERATURE REVIEW

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Review 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, objectives, 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*

1. Introduction

Scheduling is a method that determines when a specific task can be feasibly accomplished. The boundary of the scheduling problem can be defined by specifying the resources, the time duration of the task, the initial time at which it may begin, and the time by when it is expected to finish. In fact, this is a decision-making procedure that optimizes one or more objectives (Pinedo, 2004). The purpose of the scheduling

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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. For instance, consider a job shop that manufactures parts for successive assembly into end products. The due dates for parts are reliant on the assembly scheme of the finished product. If orders of parts are stuck, then the assembly of the products may be hindered. The adverse influence could be that assembly effectiveness and client satisfaction will be hammered. If an order of parts is completed earlier than the due date, it must be retained in stock up to its delivery date. The adverse influence is the build-up of inventory.

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 and Scudder (1990), Gordon et al. (2002), and Lauff and 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. Boysen et al. (2009) reviewed a mixed-model sequencing approach for reducing workload and production costs. They also classified sequencing approaches considering different objectives like setup operations and due dates. They stated that constraint programming has been superseded as a suggested solution technique by combinatorial optimization. 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, 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 principle first appears in the middle of the 1950s. Following that, the challenges linked to this were brought up to industrialised applications by considering shop layouts, shops with a number of identical machines, an operation requiring many resources at the same time, or multipurpose machines. As a result, the

level of difficulty rises (T'kindt and Billaut, 2005). The scheduling models can be classified by identifying the resource arrangement and the jobs' nature (Baker and Trietsch, 2009). To be more precise, a model may consist single machine or multiple machines. It may be static (a set of jobs that do not vary over time, ready for scheduling) or dynamic (new jobs appear continuously). 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.

Investigation of static problems usually discovers useful understandings, and later heuristic methods are used in the dynamic approach. Finally, the model may be deterministic (where certain assumptions are made with certainty) or stochastic (where uncertainty is recognized with explicit probability distributions).

In recent years, a due-window assignment has obtained a stronger focus. The approach to the due window problem can be applied in several realistic situations. For instance, the contractor is specified about flexibility concerning the supply time and is unrestricted to an exact due date, that is, orders (or jobs) accomplishment can be taken without fine in a period; this is known as the due window (J. B. Wang et al., 2020).

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, for example, various jobs are given by the same client that forms one order, or the parts of a product should be prepared for assembly simultaneously. 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 and 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. These parameters are summarized with their notation and mathematical representation, as shown in Table 1.

Table 1. Summary of objective functions used in scheduling and sequencing

Objective	Notations	Meaning	Objective Function
	C_j	Completion time of job *j*	C_j
	r_j	Release time of job *j*	r_j
	w_j	Weight of job *j*	w_j
	d_j	Due-date of job *j*	d_j
	$\propto_j$	Earliness cost of job *j*	$\propto_j$ can be any numeric value
	β_j	Tardiness cost of job *j*	β_j can be any numeric value
	N	Total jobs in the system	N
Completion time	C_t	Total completion time of jobs	$\sum_{j=1}^{N} C_j$
	C_{tw}	Total weighted *(tw)*completion time of jobs	$\sum_{j=1}^{N} (w_j * C_j)$
	C_μ	Average (μ) completion time of jobs	$\frac{1}{N}\sum_{j=1}^{N} C_j$
	$C_{\mu w}$	Average weighted (μw) completion time of jobs	$\frac{1}{N}\sum_{j=1}^{N} (w_j * C_j)$
	C_{max}	Maximum completion time of job which completes at last on the system	$max\{C_1, C_2, C_3 \dots C_N\}$
Flow time	F_j	Flow time of job *j*	$C_j - r_j$
	F_t	Total flow time of jobs	$\sum_{j=1}^{N} F_j$
	F_{tw}	Total weighted *(tw)* flow time of jobs	$\sum_{j=1}^{N} (w_j * F_j)$
	F_μ	Average (μ) flow time of jobs	$\frac{1}{N}\sum_{j=1}^{N} F_j$
	$F_{\mu w}$	Average weighted (μw) flow time of jobs	$\frac{1}{N}\sum_{j=1}^{N} (w_j * F_j)$
	F_{max}	Maximum flow time	$max\{F_1, F_2, F_3 \dots F_N\}$
Lateness	L_j	Lateness of job *j*	$C_j - d_j$
	L_t	Total lateness of jobs	$\sum_{j=1}^{N} L_j$
	L_{tw}	Total weighted *(tw)* lateness of jobs	$\sum_{j=1}^{N} (w_j * L_j)$
	L_μ	Average (μ) lateness of jobs	$\frac{1}{N}\sum_{j=1}^{N} L_j$

	$L_{\mu w}$	Average weighted (μw) lateness of jobs	$\frac{1}{N}\sum_{j=1}^{N}(w_j * L_j)$
	L_{max}	Maximum lateness	$max\{L_1, L_2, L_3 \dots L_N\}$
Tardy jobs	N_{tj}	Number of tardy jobs	$\sum_{j=1}^{N}\delta(T_j)$ $\begin{cases}\delta(x) = 1\ if\ x > 0 \\ \quad\ = 0\ otherwise\end{cases}$
	μ_{ntj}	Average number of tardy jobs	$\frac{N_{tj}}{N}$
Tardiness	T_j	Tardiness of job j	$T_j = max\{0, L_j\}$
	T_t	Total tardiness of jobs	$\sum_{j=1}^{N} T_j$
	T_{tw}	Total weighted (tw) tardiness of jobs	$\sum_{j=1}^{N}(w_j * T_j)$
	T_{μ}	Average (μ) tardiness of jobs	$\frac{1}{N}\sum_{j=1}^{N} T_j$
	$T_{\mu w}$	Average weighted (μw) tardiness of jobs	$\frac{1}{N}\sum_{j=1}^{N}(w_j * T_j)$
	T_{max}	Maximum tardiness	$max\{T_1, T_2, T_3 \dots T_N\}$
Earliness	E_j	Earliness of job j	$d_j - C_j$
	E_t	Total earliness of jobs	$\sum_{j=1}^{N} E_j$
	E_{tw}	Total weighted (tw) earliness of jobs	$\sum_{j=1}^{N} wj * E_j$
	E_{μ}	Average (μ) earliness of jobs	$\frac{1}{N}\sum_{j=1}^{N} E_j$
	$E_{\mu w}$	Average weighted (μw) earliness of jobs	$\frac{1}{N}\sum_{j=1}^{N}(w_j * E_j)$
	E_{max}	Maximum earliness	$max\{E_1, E_2, E_3 \dots E_N\}$
Early jobs	N_{ej}	Number of early jobs	$\sum_{j=1}^{N}\delta(L_j)$ $\begin{cases}\delta(x) = 1\ if\ x > 0 \\ \quad\ = 0\ otherwise\end{cases}$
	μ_{nej}	Average number of early jobs	$\frac{\mathrm{N_{ej}}}{N}$
Cost	$Total_{cost}$	Cost function for E/T of schedule for N jobs	$\sum_{j=1}^{N}(\propto_j E_j + \beta_j T_j)$

The literature on scheduling work mainly consists of the performance criteria like completion time, flow-time, tardiness, and earliness. Çetinkaya and 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. Completing the jobs before time affects inventory carrying costs such as storing and insurance costs. On the other hand, jobs that get completed after their due dates affect fines like late dues, damage to a client concern, and harm to trades.

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.

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. A classification scheme is developed and used to figure out the progress in cost minimization in scheduling and sequencing. 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.

The purpose of the review is to underline the variety of research existent in the area of scheduling and sequencing with cost minimization as the primary aim and by using advanced computational algorithms. These algorithms give easy, quick, and efficient solutions. Secondary aims pursued by different scholars are also discussed in section 5.9.

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.

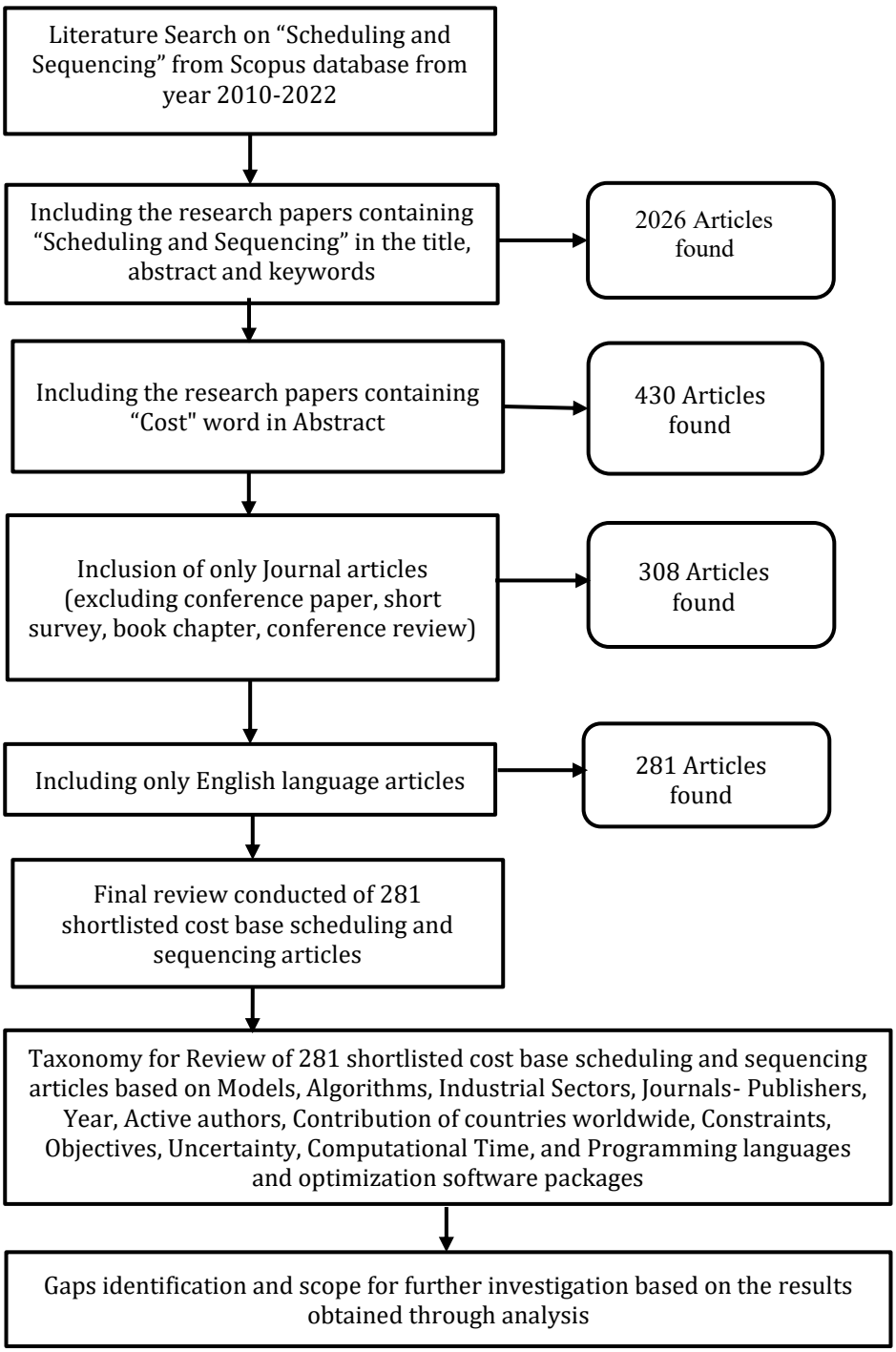

Figure 1. Framework for research study

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. The review approach is built on the content analysis approach suggested by Yadav and Desai (2016). Each research paper was thoroughly studied, and then the information was collected to represent the classification scheme from different viewpoints. This review assists as a complete base for explaining the research of cost minimization in scheduling and sequencing. 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 twelve main dimensions as mentioned below:

(1) Scheduling Models
(2) Algorithms Used
(3) Industrial Sectors
(4) Journals and Publishers
(5) Publication Year
(6) Authors in the study (concerning research papers published)
(7) Contribution of countries worldwide
(8) Constraints
(9) Objectives
(10) Uncertainties
(11) Computational Time
(12) 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. Objectives arrangements state secondary aims in scheduling and sequencing other than cost discussed in different 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. Xian-ru (2012) developed a model for sequencing static aircraft arrival and solving scheduling problems of their landings to reduce overall costs in delay.

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. Lakhan et al. (2021a) 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. Zhang et al. (2021) developed a collaborative approach to increase the efficiency of genetic programming in dynamic, flexible job shop scheduling and showed that the computational cost could be reduced. Vandenberghe et al. (2020) solved the scheduling problem by considering the emergency entry of patients on a regular schedule. 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. Liang et al. (2015) developed a surgical treatment scheduling system that manages real-time modification in the operation room. Nguyen et al. (2015) applied Automatic Programming via Iterated Local Search algorithm to find out dispatching rules with the dynamic model environment in dynamic job shop

scheduling. Savino et al. (2010) presented a heuristic method in the painting industry where a novel product demand occurred during particular production sub-periods. They demonstrated the method's usefulness in a dynamic environment to lessen the setup number for the lot sequencing to increase throughput in the metal sheets painting industry.

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. 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 et al. (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. Agnetis et al. (2015) applied the concept of game theory to a deterministic scheduling problem where two agents strive to utilize a machine.

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. Cheng (1991) is considered one of the pioneers who studied the due-date assignment problem and job sequencing using random processing times arranged on one machine. 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. Baker (2014) highlighted that problems with stochastic scheduling containing E/T have hardly been considered in the literature. 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 (2015). D. J. Wang, et al. (2019) examined the capability of pre-emptive scheduling techniques using stochastic machine breakdown, 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 and Storer (2012, 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. Tsai et al. (2021), Sun et al. (2021), Jafarnia-Jahromi and Jain (2020) described the concept of stochastic scheduling surgery to tackle patients' arrival and patient appointment scheduling problem, respectively. Zhou and Yue (2021a) and Zhou and Yue (2021b) considered stochastic service times in multistage service systems to reduce the total costs of customers' waiting time. Wu and Zhou, (2022) considered the problem of scheduling and sequencing with stochastic service durations and client's arrivals. They formulated a model with multiple stochastic linear programs to reduce the weighted sum of server staffing cost and the total expected cost of client waiting, server idleness and overtime.

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 shown in Figure 2.

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. The basic Mixed Integer Programming (MIP) problem can be represented as:

$$Z = CX$$

The above equation is a linear objective function that can either maximize or minimize given one or more constraints in the form of CX (Example: $2x_1+3x_2 \leq 12$), where $X = (x_1, x_2, \dots, x_n)$ are variables of objective function and $C = (c_1, c_2, \dots, c_n)$ are constants.

MINLP is an optimization technique that handles nonlinear problems with continuous and integer variables. The algebraic representation of the MINLP problem in its basic form is given below:

$$Z = f(x, y)$$

where *x* and *y* are the variables.

Bueno et al. (2020), Abdullah et al. (2019), Haoran et al. (2018), Mostafaei et al. (2015), and Cafaro and Cerdá (2010) applied MILP. Pautasso et al. (2019) and Cerda et al. (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. MILP was also used in automobiles, airports, and manufacturing industries for optimizing the cost of parts, aircraft, and tasks sequencing, respectively.

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. Tsai et al. (2021) formulated MILP with rapid screening and stochastic approximation algorithms to tackle planning and sequencing decisions in a surgical scheduling problem. Their investigational results showed that their suggested algorithms are better. Zhou and Yue (2021b) articulated a stochastic program and utilized a sample average approximation approach to reframe this as a mixed-integer program as advanced. This approach is altered and improved as the Benders decomposition algorithm to discover near-optimum results.

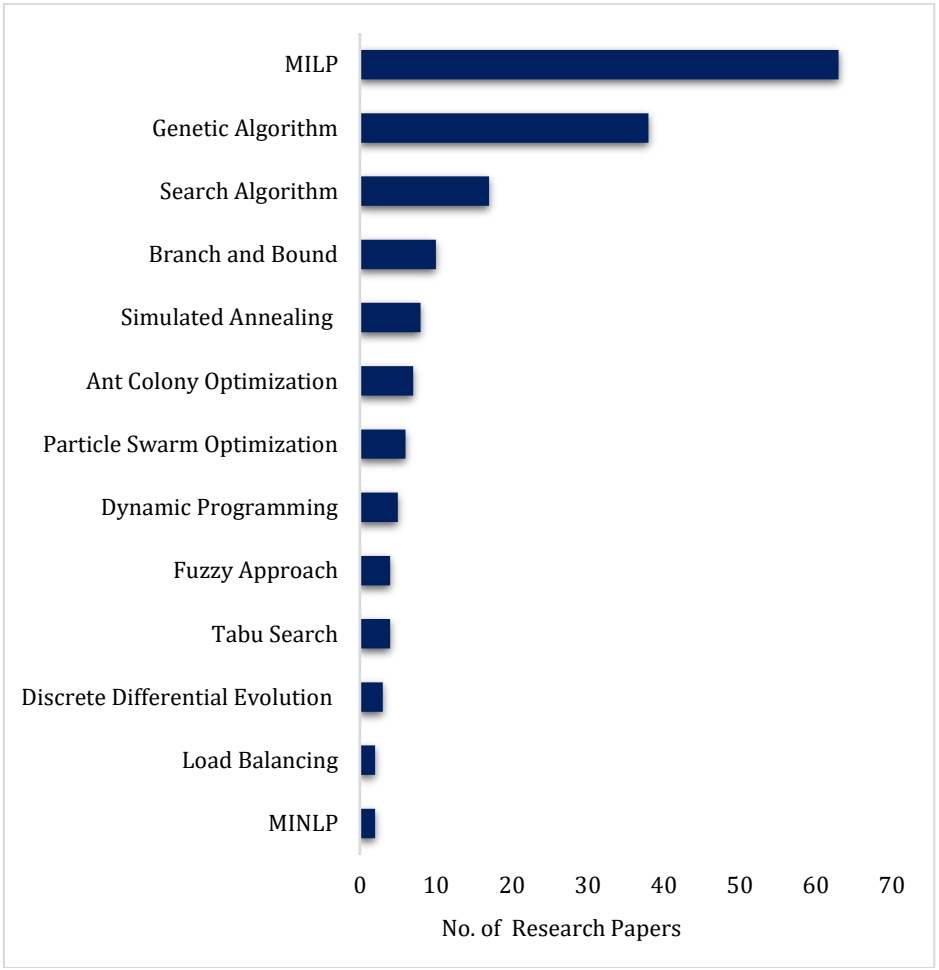

Figure 2. Solution approaches used by authors

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 et al. (2018) developed an optimal pseudo-polynomial time DP algorithm for rescheduling and for saving the overall cost of jobs in manufacturing, Mohan and Kumar (2016) adopted DP for solving the waste load scheduling problem, Lu et al. (2013) demonstrated DP algorithm to find the optimal price quotations and production scheduling in manufacturing, Chou et al. (2013) analysed DP as a scheduling framework to determine the optimal development plan of a local water supply system. Yeung et al. (2011) implemented the DP algorithm to get the optimal supply chain scheduling problem solution to reduce inventory holding costs.

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.

Domínguez-Martín et al. (2017), Rudek (2016), Chaieb Memmi and Hammani Laaroussi (2013), Lin and Chu (2013), and Eun et al. (2010) investigated the model using BB algorithm with constraints like production lines, 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. Martínez et al. (2019) used branch and check to find the best solutions to the production planning problem of the packaging industry. Canca et al. (2019) applied a model with a branch and cut in the town of Seville (Spain) for constructing a metro network.

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. Ardakani et al. (2020) presented that a heuristic algorithm works better than the mathematical model for the truck to door sequencing. Braat et al. (2019) applied an equilibrium heuristic to develop a framework for sequencing situations with selfish agents. Zhou et al. (2019) used it in flexible job shop scheduling for the assignment of machines and sequencing rules of jobs. Musavi and Bozorgi-Amiri (2017) studied the optimization of the vehicles at hubs by proposing a metaheuristic approach in CSS considering a case study of the food supply chain. Lemos and Ronconi (2015) determined the job sequence and the due dates, which reduce the probable E/T costs by applying a heuristic approach. Li et al. (2015) 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. 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. Kurniawan et al. (2020a), Kurniawan et al. (2020b), Alaghebandha et al. (2019), Biele and Mönch (2019), Weiss et al. (2019), Zhou et al. (2019), Yue et al. (2016) 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. 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. Costa et al. (2013) tested to evaluate the impact of the workers' skills on both manpower cost and makespan. 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. Zhang et al. (2018), Nonsiri et al. (2014), and Mokhtari et al. (2011) optimized the sequencing of jobs, the engineering tasks with the use of the DDE algorithm.

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. Nazif (2018), Haoran et al. (2018), and Li et al. (2015) provided an ACO algorithm that helps in the sequencing of jobs and allotting resources at the same time. 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. Xian-ru (2012) used ACO to reduce the overall delay cost by finding the aircraft's sequencing and landing times schedule. Udhayakumar and Kumanan (2010) successfully accomplished the sequencing and

scheduling of jobs and tools with the intent of reducing makespan in a flexible manufacturing system.

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 and Hengmeechai, 2017). PSO has been successfully applied by M. Z. Wang et al. (2020), Wu et al. (2019), Rohaninejad et al. (2016), Fang and Lin (2013) in different areas like manufacturing, logistics/transport, job shop, and health. 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. Sadhasivam et al. (2018) developed an improved PSO algorithm which helped in overall cost reduction for revealing epigenetic irregularities of application for cancer diagnosis by getting appropriate resources and assignment of epigenomics tasks.

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 and Khasawneh (2020) to find a near-optimal solution for scheduling medical tourists'. Wei et al. (2017) used TS for the sequencing of components, and Mobaieen et al. (2012) used TS to locate optimal solutions in a robot project. Mazdeh et al. (2010b) applied TS to obtain optimal solutions in the manufacturing industry.

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. Singh et al. (2021) used SA to optimize the schedule for pipe installation in the piping project to reduce the cost and length of project time. 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. SA with GA was used for the sequencing of several courses related to the classroom in education by Czibula et al. (2016). Areal et al. (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.

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. (2019) applied CSA in the combined scheduling of machines, automated guided vehicles, and tools in flexible manufacturing systems to reduce the makespan. Reddy et al. (2021) 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.

5.2.2.8. Search Algorithms

Authors used different search algorithms for optimization such as Variable Neighbourhood Search (Yan et al., 2014, Mokhtari et al., 2011), Iterated Reference Greedy algorithm (Pei et al., 2019), Multi-Start Iterative Search heuristic (Czibula et al., 2017), Greedy Randomized Adaptive Search Procedure (Molina-Sánchez and González-Neira 2016, Heath et al., 2013), Automatic Programming via Iterated Local Search-APRILS (Nguyen et al., 2015), Stochastic mixed integer programming based local search (Santos and 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. Tavakkoli-Moghaddam et al. (2012) mentioned that if complete data is not present, then one can use a fuzzy approach. Murugesan and Chellappan (2012), Mazdeh et al. (2010a) used the fuzzy approach due to uncertainty in real-world grid scheduling and deteriorating job scheduling problem, respectively.

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. Figure 3 shows the industrial sectors relating to CSS research work. 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 4. 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.

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 and Onal, 2020; J. B. Wang et al. 2020; Kurniawan et al., 2020a; 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. C. Wang et al. (2020) investigated instruction scheduling to achieve increased instruction-level parallelism. They used a machine learning approach to discover inter-task dependency in an out-of-order scheduling strategy. In the project management area, the researchers mostly studied sequencing activities/elements to minimize the cost. Classification of the surveyed literature by key industrial sector is summarized in Table 2. The research papers studied in the literature highlighted case studies and also involved model development using algorithms, structures, and practices in industries.

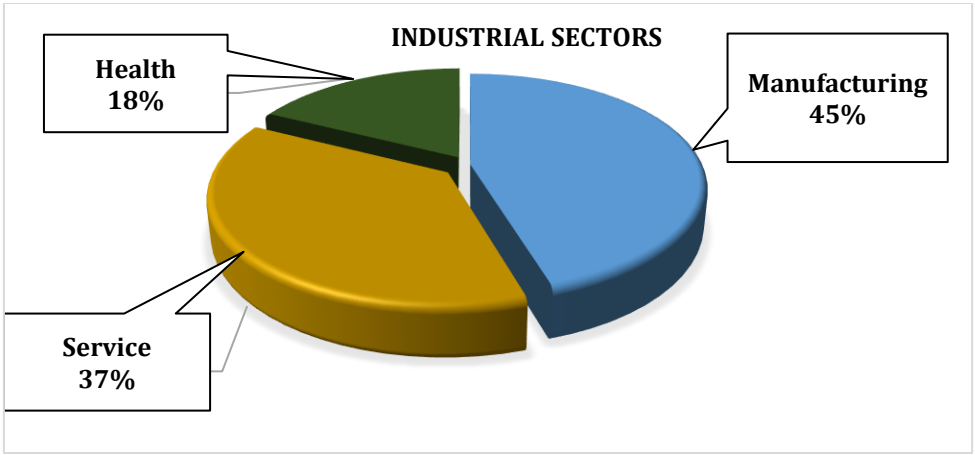

Figure 3. Article distribution using industrial sectors

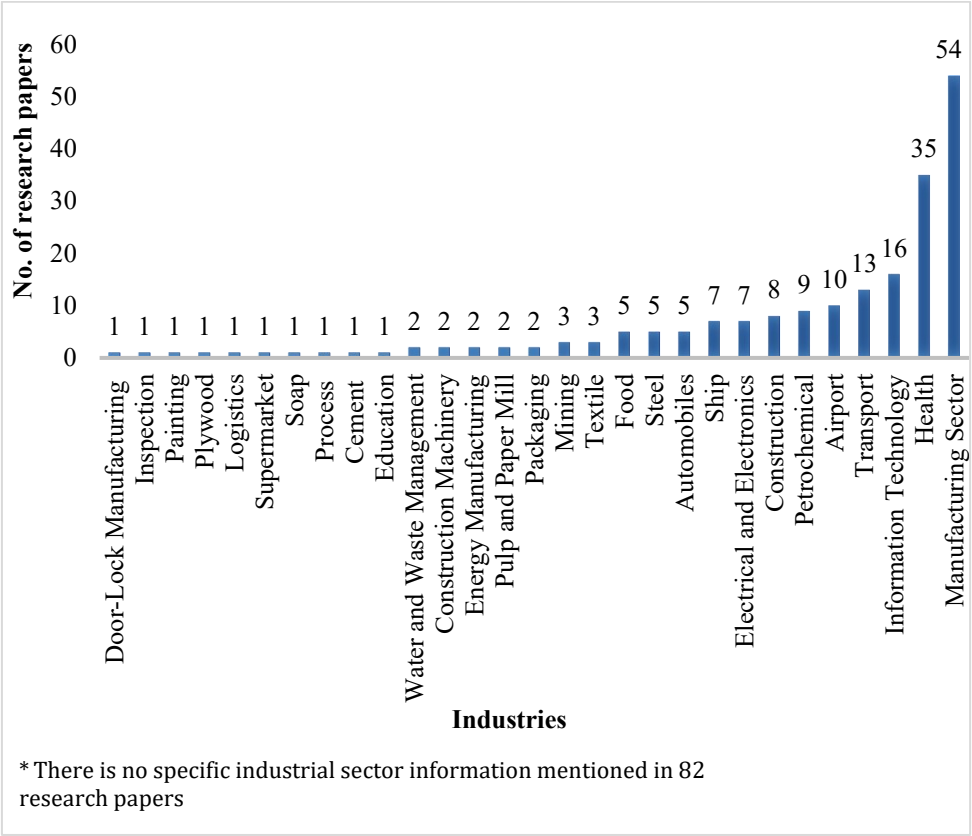

Figure 4. Research papers based on focused industries

Table 2. Summary of literature by the industrial sector

Industrial Sector	Industry	Paper
Manufacturing	Door Lock	Lin and Chu, 2013
	Plywood	Alfieri and Cantamessa, 2010
	Soap	Bhosale and Pawar, 2020
	Process	Subbiah et al., 2011
	Cement	Asad, 2011
	Construction Machinery	Seif et al., 2018; Faghihi et al., 2014
	Energy Manufacturing	Kurniawan et al., 2020b; Zhu et al. 2017
	Pulp and Paper	Martínez et al., 2018; Santos and Almada-Lobo, 2012
	Textile	Molina-Sánchez and González-Neira, 2016; Ait-Alla et al., 2014; Mathur and Süer, 2013
	Food	Carvalho and Nascimento, 2022; Shen et al., 2021; Musavi and Bozorgi-Amiri, 2017; Toledo et al., 2014; Kopanos et al., 2011

	Steel	Álvarez-Gil et al., 2022; Gao et al., 2021; D. J. Wang et al., 2019; Weiss et al., 2019; Fernandez et al., 2014
	Automobiles	Wu et al., 2021; Ferro et al., 2019; Domínguez-Martín et al., 2017; Tang et al., 2012; Areal et al., 2011
	Electrical and Electronics	Kobayashi, 2021; Cui et al., 2020; Ferro et al., 2019; Heath et al., 2013; Eguia et al., 2011; Paik et al., 2011; Ho et al., 2010
	General	C. N. Wang et al., 2022; Guzman et al., 2022; Laili et al., 2022; F. Zhang 2021; Farmand et al., 2021; Grigoriev et al., 2021; Liu et al., 2021; Said et al., 2021; Xu et al., 2021; Yamada et al., 2021; Cayo et al., 2020; Dou et al., 2020; J. Wang et al., 2020; Kurniawan et al., 2020a; Lopes et al., 2020; Alaghebandha et al., 2019; Djassemi and Seifoddini, 2019; Pei et al., 2019; Reddy et al., 2019; X. Zhang et al. 2019; G. Zhang, et al. 2018; Gao and Qu, 2018; Glazer et al., 2018; Liu et al., 2018; Lopes et al., 2018; Purohit and Lad, 2016; Rohaninejad et al., 2016; Gao et al., 2015; Li et al., 2015; Nguyen et al., 2015; Suet al., 2015; Chaieb and Hammani, 2013; Costa et al., 2013; Fang and Lin., 2013; Fumero et al., 2013; Huang and Yao 2013; Le and Pang, 2013; Lu et al., 2013; Golmakani and Namazi, 2012; Ramezanian and Saidi-Mehrabad, 2012; Gholipour-Kanani et al., 2011; Mokhtari et al., 2011; Subbiah et al., 2011; Transchel et al., 2011; Yeung et al., 2011; Barlatt et al., 2010; Barman and Lisboa, 2010; Gürel et al., 2010; Leyvand et al., 2010; Mazdeh et al., 2010b; Palaniappan and Jawahar, 2010; Paul and Azeem, 2010; Supithak et al., 2010; Udhayakumar and Kumanan, 2010
Health	Health Industry	Ballester et al., 2022; Lakhan et al., 2022a; Lakhan et al., 2022b; Shehadeh and Padman, 2022; Lakhan et al., 2021a; Pan et al., 2021; Sun et al., 2021; Tsai et al., 2021; J. Wang et al., 2020; Jafarnia-Jahromi and Jain, 2020; M. Z. Wang et al., 2020; Mandelbaum et al., 2020; Rezaeiahari and Khasawneh, 2020; Vandenberghe et al., 2020; Wu et al., 2019; Al-Refaie et al., 2018a; Al-Refaie et al., 2018b; Deceuninck et al., 2018; Haddad et al., 2018; Nazif, 2018; Sadhasivam et al., 2018; Roshanaei et al., 2017; Samorani and Ganguly, 2016; Liang et al., 2015; Saadouli et al., 2015; Azari-Rad et al., 2014; Chen and Robinson, 2014; Mancilla and Storer, 2013; Choi and Wilhelm, 2012;

		Mancilla and Storer, 2012; Gul et al., 2011; Zhao et al., 2011; Ho et al., 2010
Service	Inspection	Sinisterra and Cavalcante, 2020
	Painting	Savino et al., 2010
	Logistics	Ardakani et al., 2020
	Supermarket	Rijal et al., 2021
	Education	Czibula et al., 2016
	Water and Waste Management	Mohan and Kumar, 2016; Chou et al., 2013
	Packaging	Martínez et al., 2019; Burger et al., 2015
	Mining	Hosseini et al., 2020; Campos et al., 2018; Armstrong and Galli, 2012
	Ship	Al-Refaie and Abedalqader, 2022; Zheng et al., 2022; Gao et al., 2021; Wang and Wang, 2021; Corry and Bierwirth, 2019; C. Wang et al., 2016; Sun et al., 2014
	Construction	Xu et al., 2022; Abadi et al., 2021; Singh et al., 2021; Yuan et al., 2021; Abotaleb et al., 2020; Wah-Peng et al., 2017; Eguia et al., 2011; Feng et al., 2010
	Petrochemical	Bayu et al., 2020; Bueno et al., 2020; Abdullah et al., 2019; Pautasso, et al., 2019; Quinteros, et al., 2019; Cerdá et al., 2015; Mostafaei et al., 2015; Fumero et al., 2012; Cafaro et al., 2010
	Airport	H. Zhao et al., 2022; Rodríguez-Sanz et al., 2021; Biele and Mönch, 2019; De Maere et al., 2018; Murça, 2017; Farhadi et al., 2014; Tan, 2012; Tavakkoli-Moghaddam et al., 2012; Stiverson and Rathinam, 2011; Eun et al., 2010
	Transport	Dang et al., 2021; Canca et al., 2019; Corry and Bierwirth, 2019; Reddy et al., 2019; Shahram and Vahdani, 2019; Y. Zhang et al. 2019; Durazo-Cardenas et al., 2018; Gifford et al., 2018; Haoran et al., 2018; Domínguez-Martín et al., 2017; Murça, 2017; Wisittipanich and Hengmeechai, 2017; Mohtashami A., 2015
	Information Technology	Ali and Iqbal, 2022; Hussain et al., 2022; S. Wang et al., 2022; Yang and Shen, 2022; Gu et al., 2021; Hussain et al., 2021; Lakhan et al., 2021b; C. Wang et al., 2020; Zhao and Huang, 2020; Hu et al., 2019; Senturk et al., 2018; Kong et al., 2016; Nonsiri et al., 2014; Kim et al., 2012; Mobaieen et al., 2012; Murugesan and Chellappan, 2012

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 wherein 2 to 3 papers are published (around 1%) are listed in Table 3. Due to space limitations, journals with one research paper are not mentioned.

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 5 presents the classification of research papers with publishers' details.

Table 3. Journals classification

Source Title	Publisher	Total Articles*
Computers and Industrial Engineering	Elsevier	21
Computers and Operations Research	Elsevier	14
International Journal of Production Research	Taylor and Francis	12
European Journal of Operational Research	Elsevier	10
Industrial and Engineering Chemistry Research	American Chemical Society	7
IIE Transactions (Institute of Industrial Engineers)	Taylor and Francis	6

IEEE Access	IEEE	5
International Journal of Production Economics	Elsevier	5
Journal of Scheduling	Springer	5
Applied Mathematical Modelling	Elsevier	4
Computers and Chemical Engineering	Elsevier	4
Expert Systems with Applications	Elsevier	4
Production and Operations Management	Wiley	4
Production Engineering	Springer	4
IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems	IEEE	3
International Journal of Advanced Manufacturing Technology	Springer	3
International Journal of Industrial Engineering Computations	Growing Science	3
Journal of Industrial Engineering and Management	OmniaScience	3
Journal of the Operational Research Society	Taylor and Francis	3
Transportation Science	INFORMS	3
Aircraft Engineering and Aerospace Technology	Emerald Group Holdings Ltd.	2
Automation in Construction	Elsevier	2
Engineering Optimization	Taylor and Francis	2
Future Generation Computer Systems	Elsevier B.V.	2
Health Care Management Science	Springer	2
IEEE Transactions on Cybernetics	IEEE	2
IEEE Transactions on Systems, Man, and Cybernetics: Systems	IEEE	2
Information Sciences	Elsevier	2
Interfaces	INFORMS	2
International Journal of Industrial Engineering: Theory Applications and Practice	University of Cincinnati	2
International Journal of Manufacturing Technology and Management	Inderscience	2
International Journal of Operations and Quantitative Management	INFOMS	2
International Journal of Simulation Modelling	DAAAM International Vienna	2
Management Science	INFORMS	2
Mathematical Problems in Engineering	Hindawi	2
Operational Research	Springer	2
Transportation Research Part E: Logistics and Transportation Review	Elsevier	2

* Journals with one research paper are excluded

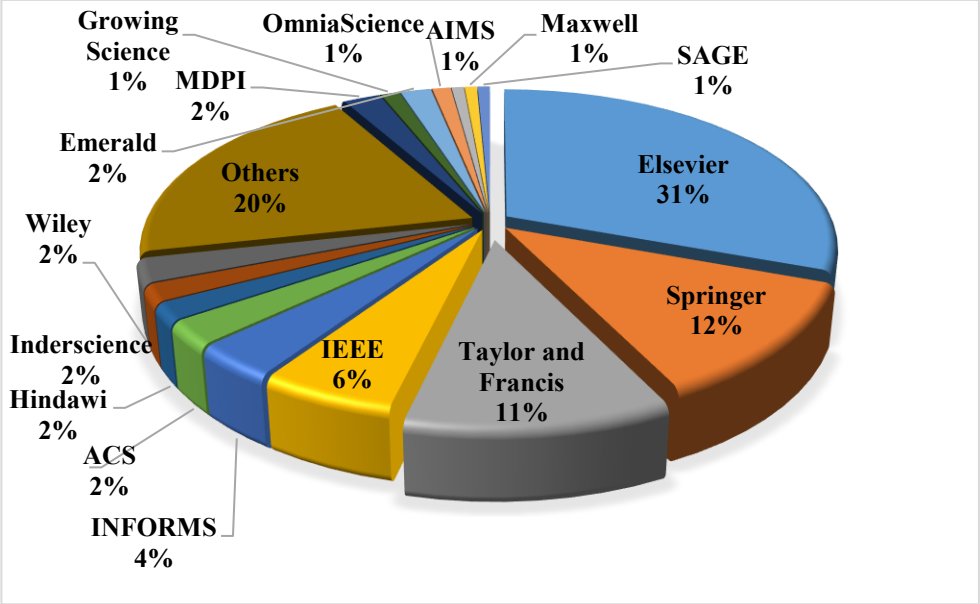

Figure 5. Research papers based on publishers

5.5. Classification of research papers based on year of publication

Figure 6 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. Some of the commendable recent research papers which described applications of CSS optimization algorithms in different fields are manufacturing (Zhang et al., 2018; Liu et al.2018), Health (Deceuninck et al., 2018; Roshanaei et al., 2017), Education (Czibula et al. 2016), Service (Haoran et al., 2018; Durazo-Cardenas et al., 2018), Project Management (Zhao and Huang, 2020; Hu et al., 2019), Computer - cloud server (Senturk et al., 2018). Still, there are some areas where the growth in several CSS works is notable.

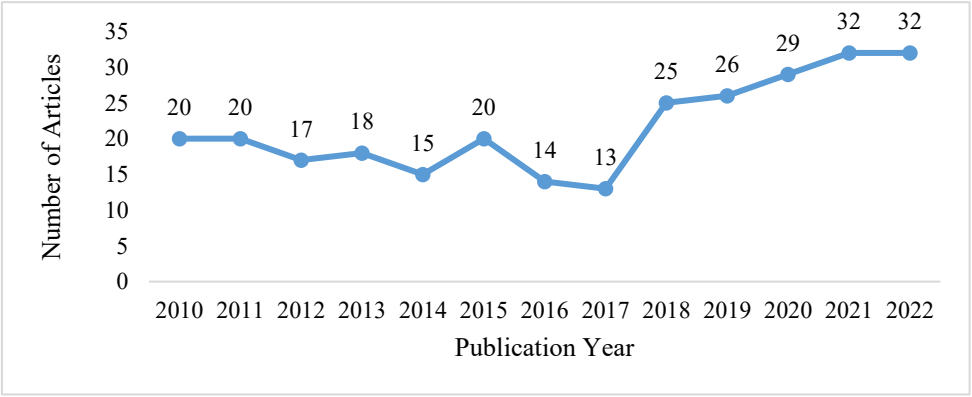

Figure 6. Research papers based on year of publication

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 The top 12 authors with three or more research papers, each contributing to publishing and demonstrating related work, are listed in Table 4. 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. While the rest, 820 authors who published one or two research papers, are not mentioned in the table due to space constraints. Fang and Lin (2013) in Manufacturing, Gul et al. (2011) in Health, and Mak et al. (2013) in appointment scheduling are the authors whose work received more than 100 citations till now as shown by the publishers.

Table 4. Top 12 authors with the most contribution in research on CSS

Name of Authors	Articles
A. Al-Refaie	5
S. Zhou	4
D. C. Cafaro	3
Y. Dong	3
X. Li	3
R. Morabito	3
J. Cerdá	3
Z. Gao	3
L. Magatão	3
A. Al-Hawadi	3
M. Elhoseny	3
Q. Yue	3

5.7. Classification of research papers based on countries

Table 5 shows that 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 (Liu et al., 2021; Dou et al., 2020; Zhang et al., 2018) focused on the manufacturing industry. The study tells that from year 2010, consistent research is there in CSS. On the other hand, United States (Sun et al., 2021, Jafarnia-Jahromi and Jain, 2020; Rezaeiahari and Khasawneh, 2020; J. Wang et al., 2020; Mandelbaum et al., 2020) 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.

Table 5. Classification of research papers based on countries

Country Name	Number of Articles
China	64
United States	39
Iran	21
India	19
Brazil	13
Spain	11
Germany	9
Netherlands	8
Canada	7
Italy	7
Taiwan	7
Argentina	6
Belgium	6
Israel	6
Jordan	6
South Korea	5
Pakistan	4
United Kingdom	4
Australia	3
Colombia	3
Hong Kong	3
Japan	3
Thailand	3
Belgium	2
Chile	2
France	2
New Zealand	2
Tunisia	2
Turkey	2
Bangladesh	1
Egypt	1
Finland	1
Indonesia	1
Malaysia	1
Poland	1
Portugal	1
Saudi Arabia	1
Singapore	1
Slovakia	1
South Africa	1
United Arab Emirates	1

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 6 shows various possible constraints in different industrial sectors focused on by the authors.

Table 6. Constraints in different industrial sectors

Industrial Sector / Industry	Constraints	Description
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 travellers.
	Time, ordering, safety, en route	Stiverson and 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.
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.
Cement Manufacturing	Quality	Asad (2011) suggested that the raw material (Limestone) must contain the required percentage of chemical elements.
Computer/ Information Technology	Deadline	Lakhan et al. (2021b) addressed that completing the internet of things application in a certain time period or earliest completion time helps achieve deadlines.
	Data skew and deadline	Gu et al. (2021) proposed an algorithm for achieving an optimum solution for execution time and thus reducing rental costs.
	Resource	Kim et al. (2012) discussed the limit to the assignment of computing elements to datasets.

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	Abadi et al. (2021) addressed the resident's safety constraints in case of fire conditions at the renovation construction site.
Electronics	Time	Cui et al. (2020) addressed the timeliness constraints to find the optimum highest temperature and variant in temperature.
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.
	Pre-ordering	Fumero et al. (2013) elaborated on batch allocation, the design of the plant, and production scheduling constraints in the flow shop.
	Planned production	Ramezanian and 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 and Azeem (2010) pointed out that the sequence of jobs on the machine should be the same for all the machines.
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 and Hengmeechai (2017) suggested that precedence constraint is vital to achieve the goal in industries.
	Warehouse space and transportation costs	Golmohammadi (2013) explained internal and external constraints like warehouse space and transportation costs in scheduling.
	Precedence, resource, time	Werner et al. (2018) discussed batch production situation constraints, precedence constraints, resource constraints, and time for operation arrangement or costs.
Health	Security	Lakhan et al. (2022a) 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.
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.
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	M. Z. Wang et al. (2020) 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.
	Time	Huang and Yao (2013) proposed that sufficient time to be allocated to an item to attain its demand quality.
	Innate constraints of the production	Le and 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 and 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.
	Due dates, operation, resource	Barlatt et al. (2010) addressed the limit to the assignment of labours across the shift and the limit to the financial aspect of the industry.
Mining	Accessibility/ precedence	Armstrong and Gallim (2012) discussed accessible blocks to be mined, limiting the amount to be mined, and limiting the duration of extraction as constraints.
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.
Petrochemical	Carryover setup	Abdullah et al. (2019) described the supplier, warehouse, a customer with

		affiliate constraints associated with the product.
Process	Resource, recipes, additional timing	Subbiah et al. (2011) modelled the constraints independently as sets of timed automata methods.
Pulp	Synchronization	Martínez 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.
Railway	Movement of the train, route of the train, speed restriction and speed reduction after track maintenance	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.
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.
Ship	Time	C. Wang et al. (2016) mentioned blocks should be transported in planning time to avoid penalty of unfilled transporter travel and tardy time.
	Channels	Corry and 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.
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.
Transportation	Flowrate lower limit	Haoran et al. (2018) modelled injection, delivery constraint, time and pipeline conditions constraints using MILP.
	Time window	Shahram and 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.
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. Classification based on objectives of research in different industrial sectors

The paper's primary aim is to focus on the work related to the minimization of cost in all the papers considered. The authors depending on their application areas have classified the cost minimization as –

- In Manufacturing related industries - production, operation, setup costs, investment, labour, inventory, hardware, maintenance, costs associated with machine idle time and overtime, and finished products inventory costs.
- In health-related industries, cost comprises surgeon, patient-waiting cost, operating room idle cost, and staff overtime.
- In service and project-related industries - The overall cost for procuring energy from the external grid, electricity cost, energy consumption cost, the cost associated to the use of fossil fuels, cost of resources, labour distribution cost, warehouse capacity costs, transportation costs, component costs, equipment compliance cost, pump operating and maintenance costs, completion time cost, transition costs and tardiness costs.

Apart from these different cost minimizations as the primary aims, authors have also considered optimizing other parameters as the secondary aim in the various industries. These secondary aims are listed in detail in table 7 below.

Table 7. Secondary aims in the different industries

Type of Industry	Aims
Airport	i. Less computation time to generate the optimal sequence of runway ii. Minimizing the time of landing the planes iii. Optimal arrival flight sequencing iv. Reducing runway delays and taxi-out times
Apparel	i. More minor delays in production orders for apparel suppliers on stochastic demand
Automobiles	i. Increasing productivity of plant ii. Reducing the completion time of production iii. Reducing manpower at the car assembly line
Cellular manufacturing	i. Minimizing the makespan and costs of intra-cell movement ii. Optimal sequence-dependent setup
Cloud server/ Computer - IT	i. Reducing services delay ii. Enhancing server utilization and minimizing makespan by sequencing resources and operations, minimizing data delay, optimizing throughput in average response time iii. Minimizing power consumption
Construction	i. Minimizing work in construction projects ii. Increasing productivity iii. Scheduling processes to reduce time as well as the cost of the project
Container terminal	i. Increasing controlling effectiveness of the loading process
Education	i. Finding an optimal sequence of classes for courses and students to enhance the performance

Electric vehicles	i.	Lessening the tardiness of services to the customer
Electronics	i.	Minimizing the time required in pulse latch, condensed sequencing overhead of elements
Energy manufacturing	i.	Minimizing energy intake and tardiness
Engineer–To-Order (ETO)	i.	Minimizing lead time
Flow shop	i.	Use of needed resources, minimizing maximum completion time
	ii.	Minimizing flow time and lateness measures by different sequencing rules of jobs
	iii.	Minimizing the aggregate work-in-process inventory
	iv.	Diminishing overall weighted tardiness
	v.	Increasing make-to-order system throughput
Food	i.	Optimizing freshness and superiority of foods during distribution
	ii.	Curtailing overall arrangement costs in the production plant
	iii.	Optimizing the production capability of the plant
Freight	i.	Increasing driver efficiency and lessening the time of transportation
Health	i.	Minimizing operating room idle time and delay in service start-time
	ii.	Minimum deviation from the patient's chosen start day and the minimum average patient flow time
	iii.	Minimizing waiting plus overtime
	iv.	Optimizing over and under-utilisation of medical resources
	v.	Enhancing patients' satisfaction by scheduling and sequencing appointments
	vi.	Minimizing appointment delay
	vii.	Reducing the makespan of operating rooms
	viii.	Minimizing execution time of schedule
Job shop	i.	Reducing the total machines' workload and makespan
	ii.	Minimizing the completion time and the cost of performing schedules
	iii.	Minimalizing makespan and setup time
Logistics	i.	Minimizing makespan and the overall penalization costs
Manufacturing/ Production	i.	Minimizing total tardiness by sequencing the jobs and planning the maintenance activities
	ii.	Attaining greater production capability and shorter throughput times
	iii.	Increasing the overall net revenue
	iv.	Minimizing earliness tardiness penalties
	v.	Shapley value for the cost

	vi.	Reducing the weighted sum of key device shortages, exploiting the weighted sum of lots processed, reducing the amount of machines used
	vii.	Maximizing machine utilization
	viii.	Lessening the waiting time for queued jobs
	ix.	Reducing the completion time of products
	x.	Minimizing the total variation in parts consumption in the assembly line and minimizing the total makespan cost
Maritime ports	i.	Minimizing overall efforts/time of the crane movement
Mining	i.	Maximizing the net present value
	ii.	Minimizing completion time
Oil/ Petroleum	i.	Minimizing computational time in demand planning
	ii.	Reducing the overall time in sending petroleum refined products from oil refineries to distribution depot
Pulp and Paper mill (P and P)	i.	Maximizing customer demand
Railway transport	i.	Profit in railway transportation project
	ii.	Minimizing travel time and delay in maintenance
Robot project	i.	Reducing the overall processing time associated with tasks in robot arm movement
	ii.	Minimizing iterations and reducing lead-time development of robot
Ship	i.	Minimizing penalty time, empty transporter travel time, and tardy time
Steel	i.	Minimizing the number of coil transitions and thus improving productivity
	ii.	Optimizing the scheduling and sequencing with constraints like width, thickness, thermal cycle, and weldability of material to minimize calculation time
Textile	i.	Minimizing the number of tardy jobs
Transport	i.	Enhancing productivity and improvement in customer service
	ii.	Minimizing total operation time in scheduling vehicles in cross-docking systems
Warehouse	i.	Minimizing the makespan of transporting the product from warehouse to customer
	ii.	Fulfilling customers' orders in less time
Waste management	i.	Minimizing overall inequity and minimizing total waste load released into the river

5.10. 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. 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. Mandelbaum et al. (2020) highlighted that patients' punctuality and service durations are uncertain and bring out a data-driven, 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. 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. 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.

In manufacturing, Purohit and 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. 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. 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. Paul and Azeem (2010) represented the uncertainties in the flow shop scheduling problem and handled them using fuzzy sets and logic.

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. Rodríguez-Sanz et al. (2021) proposed a model which manages runway usage by sequencing aircraft operations by minimizing delays. They presented a robust model of scheduling optimization by considering uncertainties in tactical working steps of aircraft operations. Durazo-Cardenas et al. (2018) analysed track incidents, inspected data and developed a model to raise degradation alarms that initiate the automatic maintenance tasks scheduling that will help in reducing uncertainty in time. 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.

5.11. 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. The experimental results demonstrated that the suggested algorithms obtain a nearly optimal schedule in reasonable computational time. Martnez 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. 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. Haddad et al., (2018) employed micro/nanofluidic biochips to automate clinical diagnosis and DNA sequencing, finding a 12.52 per cent reduction in computational time. The hybrid method, as presented by Gao and Qu (2018), solves instances very quickly and uses significantly less computing time than either MILP or constraint programming alone. They stated that the computing time was lowered by 10.9 per cent.

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. Using the TS algorithm, Mobaieen et al., (2012) developed an optimum strategy for calculating the optimal robot arm movement for processing a large number of tasks. They compared task sequencing run time using the TS algorithm to PSO, GA, and neighbourhood job search and found that TS can produce better solutions with more computational time. 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. 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.

5.12. 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, the programming languages and software packages used by the authors are identified and mentioned below.

5.12.1. CPLEX

The package is based on the idea of a Simplex algorithm and developed in C named CPLEX software. For issues involving linear programming, MIP, quadratic

programming, and quadratically restricted programming, the CPLEX optimizer offers adaptable, high-performance mathematical programming solvers. Operations researchers were able to develop novel optimization algorithms, models, and applications because of their unmatched flexibility, dependability, and performance. Wu et al. (2019), Toledo et al. (2014), Fang and Lin (2013), Lin and Chu (2013), Mancilla and Storer (2012), Santos and Almada-Lobo (2012), Barlatt et al. (2010) and Alfieri and Cantamessa (2010) developed model in CPLEX programming solver to find the optimal solution for targeted objectives.

5.12.2. GAMS

The General Algebraic Modeling System (GAMS) is an advanced modeling system for mathematical optimization. GAMS is made for modeling and handling mixed-integer, linear, and nonlinear optimization problems. The system can be used on a variety of computer platforms. The system is designed specifically for complicated, large-scale modeling applications and enables the user to create robust models that can be modified to fit different circumstances. Zhao and Huang (2020), Pautasso et al. (2019), Shahram and Vahdani (2019), Quinteros et al. (2019), Musavi and Bozorgi-Amiri (2017), Fumero et al. (2012), Tang et al. (2012), Kopanos et al. (2011), Subbiah et al. (2011) designed model of optimization using GAMS. Hadidi et al. (2011) created an optimization system employing GAMS to input the model and the branch and reduce the optimization navigator (BARON) solver to reach the best solution. The BARON solver is a computational system intended for solving non-convex nonlinear programming optimization problems to achieve global optimality.

5.12.3. MATLAB

Engineers and scientists can utilise the programming environment MATrix LABoratory (MATLAB) to design the system and to analyse the product. A matrix-based language that allows computational mathematics to be expressed in the most natural way. It comes with an editor for writing scripts that compile code, produces output, and format text into executable notebooks. Reddy et al. (2019), Roshanaei et al. (2017), Rohaninejad et al. (2016), Su et al. (2015), Le and Pang (2013), Mathur and Süer (2013), Ramezanian and Saidi-Mehrabad (2012), Mokhtari et al. (2011), and Mazdeh et al. (2010a) used the MATLAB programming solver to develop and analyse a system to determine the best course of action for the intended goals.

5.12.4. Lingo

Lingo is a straightforward tool for expressing huge problems succinctly, solving them, and analysing the answer. It makes use of the power of linear and nonlinear optimization. A robust language for describing optimization models, a fully featured environment for creating and editing problems, and a number of quick built-in solvers are all included in the Lingo package. Dou et al. (2020), Alaghebandha et al. (2019), Golmakani and Namazi (2012), and Mazdeh et al. (2010b) expressed and solved the problems by Lingo.

5.12.5. Programming languages

A programming language is a method of notation for creating computer programmes. The majority of programming languages are formal text-based

languages, while some are graphical. Computer programming languages are frequently used to create software and websites and automate processes. 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. Guzman et al. (2022), Dang et al. (2021), Lakhan et al. (2021a, 2021b), Liu et al. (2021), Sun et al. (2021), Martínez et al. (2018), implemented experiments using Python programming language. Gu et al. (2021), Yuan et al. (2021), Bueno et al. (2020), Kurniawan et al. (2020a, 2020b), M. Z. Wang et al. (2020), Zhou et al. (2019), Gifford et al. (2018), De Maere et al. (2018), Zhu et al. 2017, and Sun et al. (2014) developed simulation programs by using Java. Algorithms were programmed in C++ by Tsai et al. (2021), Biele and Mönch (2019), and Paul and Azeem (2010). Grabenstetter and Usher (2015), and Chan et al. (2011) implemented a model using VB and VB.Net programming languages respectively.

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, 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%. Shen et al. (2021) applied a GA to actual-world data of the pasta industry and achieved a reduction in makespan, 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. 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. 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. 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. 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%. To solve the mixed-integer model in patient-surgeon allocation with surgeon schedule compacting, Roshanaei et al. (2017) developed a new logic-based model that results in 45-63% cost savings per surgery. 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. They were found to be effective in the

reduction of costs by 62%. Chaieb Memmi and Hammani 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%. 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.

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, objectives, 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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