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An Innovative Approach on a Variant Heuristics-Based Machine Scheduling and Sequencing: A Case Study-Based Analysis

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Abstract: This paper presents an innovative variant heuristic approach to efficiently scheduling and sequencing machines in flow shop scheduling problems in manufacturing goals. Furniture manufacturing has grown significantly in the industrial sector, driven by rising demand for wooden products and domestic furnishings. The research examines the scheduling problems these firms meet, emphasizing minimizing makespan for effective work performance. A modified version of the heuristic approach was employed to minimize the makespan and improve job efficiency. A comparative analysis has identified the most appropriate heuristic approach to reducing the makespan. Among the others, the proposed innovative variant heuristic approach minimizes the makespan with an anticipated margin of error of 3.6 percent, which provided the best result. The paper emphasizes the significance of machine scheduling and sequencing in enhancing efficiency in the furniture manufacturing industry.

Keywords: Scheduling, flow shop, heuristics approach, make-span, processing time

1 Introduction

Scheduling and sequencing (SAS) have recently been high priorities for any manufacturing and industrial company. Sequencing exists in addition to the sequence of operations. As a result, work progresses from one task to the next, and employees are given specific times to complete their assignments according to a prescribed schedule.

Real-world production and industrial settings may benefit from SAS since it helps to promptly increase productivity, product quality, and market need fulfillment and decrease idle time, flow time, and equipment leasing expenses. Sequencing and scheduling are essential in operations and production management. Manufacturing and service sector decision-makers always look for better ways to manage production resources. Timelines are helpful in many everyday contexts as well [1]. Utilizing scheduling and sequencing, several service and manufacturing firms arrive at conclusions. It distributes resources (machines) across work groups using predetermined time limits to maximize objectives. Scheduling production may help increase efficiency and decrease expenses—the manufacturing sector battles daily to create a workable schedule that satisfies manager objectives. Using the same resources to make several commodities requires expensive setup and switch processes, interrupting manufacturing. Thus, any manufacturing or service company's continuous improvement effort must include setup reduction. It's more critical if a corporation wants to adapt to shorter lead times, smaller batch sizes, and higher quality [2].

1.1 Machines scheduling and sequencing

The transportation, healthcare, hospital, computer, production planning, textile, roller bearing, building, and military industries face scheduling issues. We call it ”sequencing.” The Order handles tasks on a variety of machines. Staff, equipment, and other activities have specific beginning and ending times and managing machine operations and resources. There are scheduling problems at the store. Shops that deal with scheduling include job, flow, mixed, open, and so on. In this essay, we will go over many scheduling and sequencing options. The ideal scheduling strategy has been the subject of several investigations. The available solutions vary in two important ways. Prioritize computation time after solution

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quality. It was developed to implement Johnson's approach, dispatching rules, exact algorithms, heuristic algorithms, and meta-heuristic algorithms.

1.2 Single-processor machines

One machine process 'n' workloads in single-processor scheduling. This subject schedule 'n' jobs on one computer to reduce performance. Different arrangements might be formed for independent and dependent employment. Whether the job plan is separate from the process order determines a single-machine scheduling problem with independent or dependent jobs—these performance measures schedule independent work [3]. Maintaining the same make span for each sequence reduces mean flow time, maximum lateness, overall tardiness, and scheduling issues. Therefore, it does not measure performance. Single-machine scheduling with parallel processors uses several machines [3]. Run numerous jobs on one machine [4] using the lowest processing time, longest processing time, early due date, first-come-first-served, etc.

1.3 Parallel machine scheduling

If all jobs in each operation have arbitrary tij, an unrelated parallel machine scheduling problem can be examined. This schedule ignores related machine jobs. Machine, work, and other technology variances may cause this. This performance measure cuts makespan. Planning single-operation jobs on m parallel computers will reveal each machine's latest job completion time. Maximum job completion time, or makespan, is a critical comparable machine scheduling performance parameter [4].

1.4 Open shop scheduling

An open shop scheduling problem distributes 'n' jobs across several machines. Tasks may be completed in any order since there is no process sequence. There is no process sequence; therefore, tasks may be completed in any order. Workflows that shorten the time it takes to process all tasks are ideal [4].

1.5 Shop-flow scheduling

Flow shops have machinery that is ordered in sequence. The gadgets at the start, middle, and end are all linear. Unlike a machine shop, a flow shop may not utilize a particular machine. Another approach is to switch computers [5], and so on.

1.6 Related work

When there is a need to arrange many jobs in a specific sequence, problems related to scheduling and sequencing come to light. Every organization uses scheduling and sequencing techniques to efficiently allocate resources to tasks to optimize productivity while minimizing resource usage. This section contains several research papers that have been presented.

Sarfaraz and Ashok used meta-heuristics to review machine sequencing and scheduling. Because of its multi-solution capabilities and affordable time-to-market, this technique solved NP-hard problems bet-ter [6]. Jürgen et al. trialed production order scheduling heuristics. It was also a case study to examine how sequencing and assignment affected performance measures. The analysis captured the problem's complexity despite being a discrete event [7]. The Santos et al. study examined how sequencing and as-signment heuristics affect performance measures. Their discrete event simulation showed the case's in-tricacy. Dissimilarity also affected production orders [8]. The multi-objective scheduling problem Srinath came from an industry sponsor. Machine eligibility, sequence-dependent setup times, limita-tions, and parallel machines were involved. The problem was to reduce makespan, lateness, and setup times and improve production quality in a fabric dying industry by introducing two new objectives: col-or preference for smooth color transitions and shade consistency for smooth shade transitions and simi-lar machine colors [9]. Francisco and colleagues solved a sequence-dependent setup and preventive maintenance problem requiring job sequencing. The complexity of the issue made exact approaches challenging to implement. Researchers used meta-heuristics to fix it [10].
Schneiderjans et al. developed a heuristic scheduling method. A large U.S. manufacturer supported the system's presentation [11]. Seung and Prita examined all areas of JS-FMS sequence-driven scheduling op-timization and prediction—analysis of current literature [12]. Socorro and Helio found 46 1992–2016 case studies. The most-studied challenge was the hybrid flow shop [13]. Mohammed et al. created a Heuris-tic-Based Method Genetic Algorithm (DAS/GA) to schedule big parallel machines on a shared server, saving time. The DAS-h method considerably improved G.A. performance for large-scale situations where the M.I.P. failed and for difficulties caused by lots of search space [14]. Duygu et al.'s textile in-dustry scheduling study addressed job splitting and sequence-dependent setups. Actual loom scheduling issues were also examined [15]. The flow-shop problem, investigated by Potts and Chris, requires exe-cuting each work without preemption on the Initial machine and then on the Next one after its release date [16]. A real-world manufacturing system inspired Jairo et al.'s short-term production scheduling study. They scheduled numerous jobs on one and identical parallel machines to reduce task time [17]. Hyper-heuristic genetic programming was used by Fangfang et al. to multitask. The system was evalu-ated in flexible job-shop scheduling circumstances [18]. Jose et al. classified span minimization rules for Permutation Flow shops. Though it covered past developments, the framework also suggests future re-search directions [19].
Setup time scheduling challenges were reviewed by Ali et al. Batch, non-batch, and sequence-dependent setups were the problem types. Literature was also grouped by shop environment: flow shops, single machines, parallel machines, and job shops [20]. Pankaj and Ashwani undertook an SDST flow shop scheduling study. Their MHGA reduced total weighted square delay and make-span. They compared it to other genetic algorithms [21]. In a hybrid flow shop scheduling problem, Liao et

al. specified two se-quence-dependent setup times: one based on task order and the other on work order and machine as-signment. The N.E.H. algorithm calculated three heuristics to reduce energy consumption costs. First, EPRA exam-ines processing energy usage. Setting up time and energy consumption costs are considered by ESRA. Third, ESPRA produces fictional jobs using EPRA and ESRA [22]. Habtamu studied a makespan-reducing scheduling technique. Scheduling was optimized using a shifting bottleneck heuris-tic. He examined production system paths using Lekin software [23]. Planning and lot-sizing in a capac-itated flow shop were studied by Deeratanasrikul et al. The problem is multiple-stage production with heterogeneous machinery and sequence-dependent setup time. The setup time for each manufacturing stage could not maintain the triangle inequality [24]. The multi-objective flexible job-sop scheduling al-gorithm developed by Vahid and Ghorbanali was for a manufacturing facility with parallel machines and maintenance costs. We then created a new mathematical model and used two meta-heuristic algo-rithms—a hybrid genetic algorithm and simulated annealing. Finally, the study's results were compared to LINGO software solutions [25].
Álvaro and John studied a small footwear manufacturing company. In a small footwear company with flow shop machine characteristics, sequencing n jobs in m operations reduced job completion time. The project created a plant-efficient scheduling algorithm using WinQSB and Lekin metaheuristic algorithms [26]. MacCarthy and Jou discussed the benefits of case-based reasoning in expert scheduling system de-velopment. The scheduling system they designed and implemented was for process industries. Se-quence-dependent setup times are a notorious production scheduling issue [27]. The TTP literature re-view by Koulamas evaluated 1//T and P//T heuristic algorithms. This survey examined and critiqued the TTP's algorithms. The large body of literature on the subject after 1990 was not included in the previous survey, warranting this. He reviewed the algorithms, tardiness, and 1/T contingency strategies. The new method worked better [28]. They compared algorithms for solving the m machine stochastic flow shop problem. To reduce expected makespan. Heuristics inspired by literature were also surveyed and compared on test problems [29]. The Fereshteh et al. solution reduced cable manufacturing costs. They also suggested two hybrid metaheuristics for cable manufacturing company scheduling. These al-gorithms combine tabu search and simulated annealing. Case-based rules and theorems allowed the two algorithms to reach a particular initial solution [30]. Shih-Wei and Kuo-Ching studied amplifier assem-bly company scheduling issues. Included were setup and precedence delays. Additionally, they proposed a new mixed-integer programming model to reduce makespan [31]. Ali et al. Tabu Search (T.S.) algorithm can schedule a hybrid flow shop's sequence-dependent setup. They described and analyzed the T.S. approach. According to the study, T.S. is better than RKGA [32]. Sari and Kumral created this meta-heuristic approach. They combined processing, memory, and inference to improve solution efficiency. Meta-heuristics were discussed in mining production scheduling [33]. Masoud teams. Mixed integer models were proposed to solve sequence-dependent setup times in non-identical parallel programming. There was also a mathematical model for awareness, teamwork, and learning [34]. Kenneth evaluated heuristic methods for scheduling jobs on a single machine to re-duce lateness. He also analyzed knowledge of viable solutions to the difficult problem. They also exam-ined theory-derived natural approaches [35]. Nordin and Fatimah proposed an algorithm to reduce de-lay and earliness costs in an n-job single-machine scheduling problem with common due periods. An easy-to-implement algorithm with n iterations was cost-effective for large and small problems [36].
An-other way to schedule cell positions, Muthukumaran and Muthu invented the Nagare cell to help a struggling manufacturer. In addition, they developed step-by-step heuristic scheduling algorithms [37]. Sockalingam, Panneerselvam. Single-machine scheduling with uniform parallel processors literature was classified into 14 primary and secondary scheduling categories. Three miscellaneous issues were included, creating seventeen categories. We discussed flow time, delay, and lateness. The literature in each cat-egory was thoroughly reviewed [38]. Minimum wages in a job shop with unidirectional transport and non-renewable resources were studied by Abdelkader Hadri et al. Due to these constraints, scheduling tasks with multiple components can be difficult. Using priority rule heuristics, the authors solved this problem in various configurations. From a makespan perspective, the heuristic JSSPT cum was better [39]. As the automotive industry transitions from mass production to mass customization, block batch constraints in the classical C.S.P. model are common. Yingjie Yu et al. addressed them. A mixed-integer linear programming formulation and two math-heuristic algorithms were proposed to solve the prob-lems. The first algorithm is a constructive heuristic that solves problems quickly. The second algorithm uses data-driven search to produce high-quality, real-world solutions. Computational experiments showed the efficacy of the new methods and provided planning insights [40]. H.A.J. Crauwels et al. set time penalties for processing jobs from the same family combined in a single-machine scheduling prob-lem with multiple families. Preventing late jobs was the goal. Local search heuristics with low computa-tional requirements were evaluated for online scheduling. They conducted experiments to evaluate the heuristics' solutions [41]. For a flow shop scheduling problem with four jobs and ten machines, Hossain et al. compared three makespan heuristics. Each heuristic produced the optimal solution with a makespan of 470. This research could be used to choose efficient heuristics for similar problems and larger problems with different assumptions [42]. Ajay and Rajan

tried to minimize the makespan in a flow shop scheduling problem by ordering jobs and choosing the minimal makespan combination. For flow shop batch-processing machines, the goal was to reduce makespan [43]. Using Newsvendor cost, Farzaneh et al. proposed heuristic surgery sequencing. They contrasted it with two common heuristics: ordering surgeries based on duration variance and asking all patients to be present in the morning to avoid idle costs. On simulation and real hospital data, the authors showed that their heuristic approach outperformed others and significantly improved hospital revenue and patient satisfaction [44]. Woong et al. developed a two-stage heuristic for emergency department nurse scheduling. Excel was used to generate schedules that met hard and soft constraints efficiently. More quickly than 0-1 programming, it could produce good solutions. Its user-friendliness, cost-effectiveness, and ability to reschedule were practical [45]. Dagmara et al. wanted to reschedule production to reduce processing time and compare two heuristic algorithms for scheduling. Only one algorithm outperformed the loop approach for pro-duction process scheduling [46]. Koch et al. solved a dynamic demand, backlogging, se-quence-independent setup times, and specific constraints off-road tire lot-sizing problem. Their solution was a mathematical model and a hybrid sequential approach. Their solution worked with 170 items on 70 machines and 42 periods. Method reduced resolution time and optimized two management KPIs by 32 percent and 13 percent [47]. Proposed heuristic algorithm for parallel machine weighted tardiness scheduling by Rodrigues et al. One sequence is used to optimize a multi-machine schedule using iterated local search with generalized pairwise interchange moves. It found optimal solutions in most cases with 2–4 ma-chines and up to 50 jobs [48]. Mehmet comp. Addressed the flexible job shop scheduling problem with maintenance activities and proposed a two-phased particle swarm optimization (PSO) heuristic algo-rithm to minimize makespan and critical machine workload by introducing a new weight concept con-sidering each operation's wear and aging effect on a machine. The algorithm performed well on three benchmarks [49]. According to Josefa et al., sequence-dependent setups and parallel machines solved a capacitated lot-sizing problem for automotive bi-part injection molding. Second-tier suppliers that make similar plastic parts for the right were studied. Automobile left sides require separate inventories due to discards. MILP-based multi-machine models were proposed to improve production scheduling and se-quence management [50]. Eustaquio. Al made a heuristic solution for the single-machine scheduling problem with a standard due date and different job-ready times. Numerical experiments showed how efficient and robust the method is. New research will examine the multiple-machine cases and situations where each job has an earliness and tardiness penalty [51]. Siraj, H., and Bareduan studied optimized flow shop scheduling. Sequence selection improves modified heu-ristics used to solve the problem. These modified heuristics solved up to 20 jobs to reduce makespan. The modified and N.E.H. heuristics were then compared [52]. Gonzalez et al. solved a manufacturing com-pany's scheduling problem by scheduling over 200 jobs on unrelated parallel machines daily for various constraints and objectives. Modeling the NP-hard problem as an unrelated similar machine problem with machine eligibility and sequence-dependent setup times minimized total tardiness. Close-to-real-time constructive heuristics were studied for the company's decision support system [53].

Specifically, we investigated the case study problem of scheduling best and sequence machines along a production line. We need data from case studies to optimize the scheduling and sequencing of machines in the manufacturing line to employ heuristic approaches. The use of a heuristic approach to the scheduling and sequencing of manufacturing machines is the primary purpose of this study. The particular goals of the study are as follows:

- Minimizing the total amount of time required to do all of the tasks;
- Reducing the overall amount of delay;
- Reducing the total number of late jobs;
- Reducing the amount of time it takes to complete a task.

2 Materials and Methods

An example of applying the algorithm to data and getting the necessary results is provided, along with methods and algorithms for scheduling and sequencing machines.

The fundamental guidelines To schedule jobs across numerous work centers, one might use Johnson's rule. Its principal goal is finding the best order of operations to decrease makespan (the total time needed to do all jobs). It also lessens the amount of downtime between the two offices. The approach reduces the make-span when there are two task centers. The procedure also finds the shortest make-span under certain extra limitations when dealing with three labor centers. Several prerequisites are necessary for the method to work.

– There must be a certain amount of time for each job;

– The sequence and length of jobs must not be incompatible with one another;

– Before being transferred to the second location, all tasks must be completed and processed at the initial center.

2.1 Nomenclature

The following terminology is used in the development of the model, as shown in Table 1.

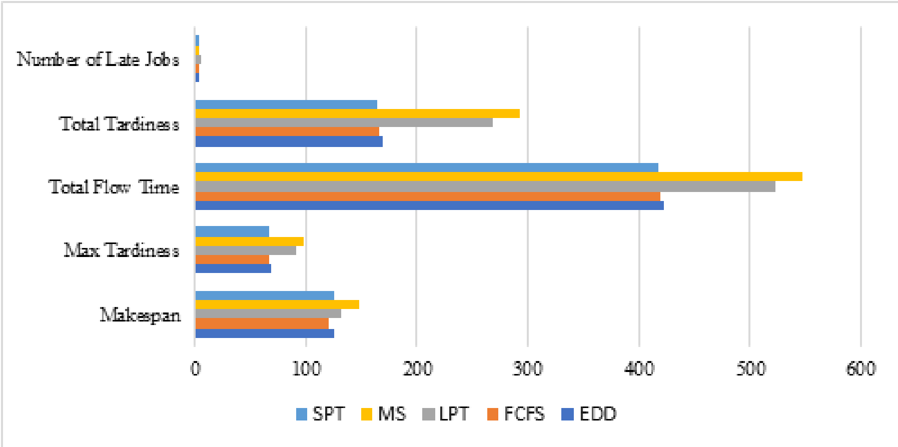

Fig. 1: Scheduling results using LEKIN software

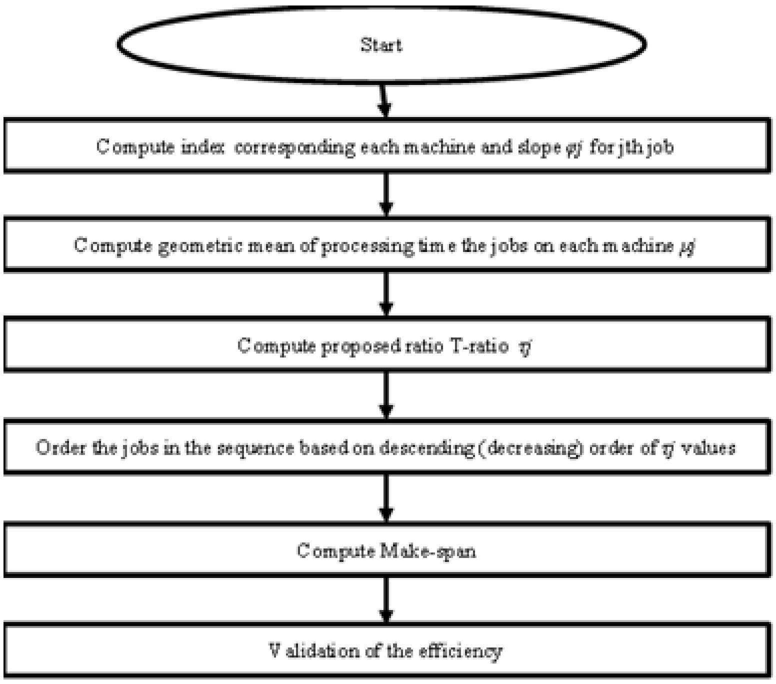

Fig. 2: Flow chart of proposed heuristic

2.2 Heuristic Method

This research employed a heuristic approach that extended Palmer's Algorithm. Due to the complexity of optimization problems, several methods cannot provide a fast and accurate solution. Several approaches have been proposed to avoid such issues that are intended to provide an improved approximation of the exact answer. These techniques, known as heuristics, are founded on experts' knowledge, and are designed to facilitate the search process [54,55,56]. We defined Palmer's Algorithm and its extension below.

2.3 An Innovative Approach on a Variant Heuristics
This heuristic comprises the following steps as follows.

Step 1: For n job and m machine static flow shop problem, compute index corresponding each machine and slope φ_j for jth job as follows.

$$Q_i = m - (2i - 1); \quad (1)$$

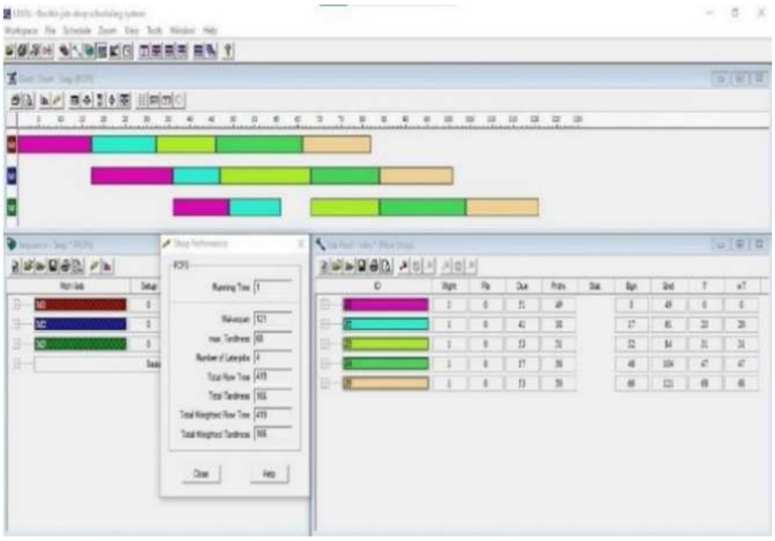

Fig. 3: Optimal result using Lekin software

Table 1: Modeling notations

Notation	Description
m	indicate to Machine
n	indicates to Job
p_j	indicate to Processing time: It is time required to process the jobs
r_j	indicate to Ready time: the point of time at which the job j is available
d_j	indicate to Due date: It is a time at which job to be completed
C_j	indicate to Completion time: It is a time at which job to is completed in sequence
F_j	indicate to Flow time: also called as Turnaround time, is the time a job j spends in a system given by (C_j - r_j)
C_{max}	indicate to Makespan: It is the time from processing start on first job in sequence until all the jobs are completed.
L_j	indicate to Lateness: the amount of time by which the completion time of job j exceeds its due date, given by (C_j - d_j)
T_j	indicate to Tardiness: the lateness of job j if it fails to meet its due date or zero otherwise and is given by max (0, L_j)

$$\varphi_j = -\sum_{i=1}^{m} Q_i \rho_{ij}; \tag{2}$$

Step 2: Compute geometric mean of processing time the jobs on each machine μ_j in the following manner.

$$\mu_j = \prod_{i=1}^{m} \rho_{ij} \tag{3}$$

Step 3: Compute proposed ratio T-ratio τ_j as.

$$\tau_j = \varphi_j / \mu_j \tag{4}$$

Step 4: Order the jobs in the sequence based on descending (decreasing) order of τ_j values.

2.4 Lekin software

However, the Lekin software can handle various machine scheduling situations, including single machine scheduling problems, parallel machine scheduling problems, flow shop and job shop scheduling problems, and flexible flow shop and job shop scheduling challenges. Initially, the process involved human selection of the machine environment and manual input of machine and job data. We selected the scheduling technique from the toolbar after completing the requisite data. There are two distinct categories of scheduling methods: rule-based methods and heuristic approaches. The rule-based techniques encompass a range of scheduling tools, including ATCS, EDD, MS, FCFS, LPT, SPT, WSPT, and CR. On the other hand, the heuristic methods consist of the standard SB routine, shifting bottleneck/ sum (wT), shifting bottleneck/ Tmax, and SB-LS (FFS decomposition). The study also used a heuristic scheduling approach using the Lekin software system.

2.5 A Case Study

Assessing the flow shop scheduling problem enhances machine performance and optimizes processing time. The study used the LEKIN software for further processing and comparison and a new variation of Palmer's heuristic

Table 2: Operation time matrix for 5 jobs and 3 Machines

Jobs	Duration (Hours)		
	M1	M2	M3
J1	17	19	13
J2	15	11	12
J3	14	21	16
J4	20	16	20
J5	16	17	17

algorithms to investigate real-world example problems. Scheduling is a method used in various production and service sectors to decide which machines will perform tasks. Accordingly, we streamlined the production time. In this study, the model utilized in the furniture industry is denoted as n/m/Fj/Cmax.
Furthermore, we have considered five job tasks and three machines. The table provided enumerates the machines and corresponding jobs

The subsequent section presents detailed information regarding the available tasks and the correspond-ing apparatus. The furniture items within the room have been assigned labels for identification purposes. Specifically, the dressing table has been designated as J1, the d as J2, the drawer as J3, the kitchen cabinet as J4, and the door as J5. Machine 1 (M1) is a wood-cutting apparatus, Machine 2 (M2) is an assembly device for fitting components together, and Machine 3 (M3) is a painting mechanism.

3 Results and Discussion

Multiple methods and algorithms were used in this study to arrive at its results. These methods and algorithms were then implemented on the data, and the outcomes were presented and compared so that the most effective method could be selected.

3.1 Using Johnson's algorithm

Step 1. Find, min (M1i), max (M2i), min (M3i)
i.e., min (M1i)= 14, max (M2i)= 21, min (M3i)= 12
Step 2. Check the following conditions:
i. $min(M1i) \geq max(M2i)$
ii. $min(M3i) \geq max(M2i)$
We can apply Johnson's algorithm if at least one condition is satisfied.
i. $min(14) \geq max(21)$; Not satisfied
ii. $min(12) \geq max(21)$; Not satisfied
Now, we Conclude that Johnson's algorithm cannot be applied, and we used a developed novel variant heuristic algorithm.

3.2 Using a developed an Innovative approach on a variant heuristic algorithm

Step 1: For the n job and m machine flow shop problem, we computed the T-ratio(τ_j) for jth job in Table 3.

Step 2: Order the jobs in the sequence based on descending order of τ_j values.
In decreasing order sequence, the jobs become:
J3-J5-J4-J2-J1.

Step 3: Calculated make span of the given jobs with the given machines in optimal value and idle time as followed in table 4.

Makespan= 114

Idle time for M1= 0+0+0+0+0+(114-82) =32

Idle time for M2= 14+0+0+0+3+(114-101) =30

Idle time for M3= 35+1+0+0+0+(114-114) =36

Total Idle time= 32+30+36= 98

Step 4: Calculate lower bond and efficiency

$$LB1 = \sum \rho_{i1} + min(\rho_{i2} + \rho_{i3}) = 82 + 23 = 105$$
$$LB2 = min\rho_{i1} + \sum \rho_{i2} + min\rho_{i3} = 14 + 84 + 12 = 110$$
$$LB3 = min(\rho_{i1} + \rho_{i2}) + \sum \rho_{i3} = 26 + 78 = 104$$
$$LB = \max(LB1, LB2, LB3) = 110$$
$$\%error = (Makespan - LB)/LB * 100$$
$$\%error = (114 - 110)/110 * 100 = 3.6\%$$

3.3 Using LEKIN software system

It is imperative to input the requisite data, including the number of machines and jobs, to operate the LEKIN software effectively.
Additionally, the processing time for each job on each machine must be provided. By default, the system accurately displays the total processing time when the data above is linked
The LEKIN program presented below displays the duration of each job's flow time, the scheduling rule used, and the corresponding values for maximum tardiness, total tardiness, make-span, and number of late jobs. These calculations are outlined in Table 5.
The analysis of the preceding table reveals that the First-Come-First-Serve (FCFS) approach exhibits su-perior performance compared to alternative scheduling rule techniques. This is evident from its signifi-cantly lower values for key performance metrics such as Makespan, Max Tardiness, Total Flow Time, Total Tardiness, and Number of Late Jobs. The FCFS method can be effectively implemented in the Lekin software, as illustrated below.

3.4 Comparison of heuristic methods

Table 6 exhibits a comparison of the make-span using several heuristic approaches.

Table 3: Calculation for T-ratio

Job	Q_1 3-(2*1-1) =2	Q_2 3-(2*2-1) =0	Q_3 3-(2*3-1) = -2	ϕ_j	μ_j	τ_j
1	17	19	13	-8	16.1	-0.496
2	15	11	12	-6	12.6	-0.478
3	14	21	16	4	16.8	0.239
4	20	16	20	0	18.6	0.000
5	16	17	17	2	16.7	0.120

Table 4: Make-span using an Innovative approach

Jobs	M1		M2		M3	
	In	Out	In	Out	In	Out
J3	0	14	14	35	35	51
J5	14	30	35	52	52	69
J4	30	50	52	68	69	89
J2	50	65	68	79	89	101
J1	65	82	82	101	101	114

Table 5: Scheduling results using LEKIN software

	Makespan	Max Tardiness	Total Flow Time	Total Tardiness	Number of Late Jobs
EDD	126	69	422	170	4
FCFS	121	68	419	166	4
LPT	133	92	524	269	5
MS	149	98	547	293	4
SPT	125	68	417	165	4

Table 6: Comparison of heuristic methods

Techniques	Makespan
A developed variant heuristic method	114
FCFS rule	121
EDD	126
SPT	125

4 Conclusions

To effectively and efficiently solve problems of this intensity, it is recommended to use the heuristics approach. The effectiveness of this method may be extraordinary, and the rapidity at which it can be achieved is remarkable. The expected results are likely to occur due to the system's implementation. The existence of a local minimum, where conventional approaches cannot make any more advancements, is thus seen as beneficial. Therefore, considering the indicated condition's integrity, this conclusion remains acceptable. This strategy is often used in situations that include computational problems with optimization.

However, there is no assurance that the most efficient solution will be identified by using this approach. Nevertheless, if we are open to embracing a solution that falls within a range of 0-4 percent deviation from the best answer, there might still be benefits to using this strategy. It is still necessary to ensure the identification of the optimal solution.

This research has focused on an advanced version of the heuristic technique to reduce make-span and optimize performance resources. A comparison study identified the most appropriate heuristic approach for minimizing the problem. The outcomes of the five jobs using three machines are shown in Table 4. Based on a developed novel variant of the heuristic method, the expected make-span is 114 minutes, with an expected margin of error of 3.6 percent. By comparison, the FCFS (First-Come-First-Serve) technique, when combined with the LEKIN software, predicts a make-span of 121 minutes. The approach above highlights the need to minimize the overall time needed to complete the given tasks for the five machines.

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References

[1] Senthilkumar, P., and Narayanan, S. Literature review of single machine scheduling problem with uniform parallel machines, (2010).
[2] N. Tyagi., R. P. Tripathi and A. B. Chandramouli, Three machines Flow shop Scheduling Model with Separate Setup Times, IEEE Int. conf. on Emer. Trends in Comm. Tech. (ETCT), GEU, Dehradun, Nov.18-19, (2016).
[3] Parveen, Sultana, and Hafiz Ullah. Review on job-shop and flow-shop scheduling using, Journal of Mechanical Engineering 41,2, 130-146, (2010).
[4] Tyagi, Neelam, R. P. Tripathi, and A. B. Chandramouli. Sequencing and scheduling methodologies. Proceedings of National Conference on Future Innovations and Research , Science and Technology. Vol. 22, (2017).
[5] Montoya-Torres, Jairo R., et al. Machine scheduling with sequence-dependent setup times using a randomized search heuristic, 2009 International Conference on Computers and Industrial Engineering. IEEE, (2009).
[6] Jenab, Kouroush, Ahmad Sarfaraz, and Mohammad T. Ameli. A conceptual design selection model considering conflict resolution, Journal of Engineering Design 24,4, 293-304, (2013
[7] Strohhecker, Jürgen. Hamann, Michael. and Thun, Jörn-Henrik. Loading and sequencing heuristics for job scheduling on two unrelated parallel machines with long, sequence-dependent set-up times, International Journal of Production Research, 2016, 54.22: 6747-6767.
[8] Santos, F. Charrua, and Pedro M. Vilarinho. The problem of scheduling in parallel machines: a case study, Proceedings of the World Congress on Engineering, 3, (2010).
[9] Srinath, N. A Study of Scheduling Problems with Sequence Dependent Restrictions and Preferences, (2022).
[10] Angel-Bello, Francisco, et al. A heuristic approach for a scheduling problem with periodic maintenance and sequence-dependent setup times, Computers and Mathematics with Applications 61,4, 797-808, (2011).
[11] Schniederjans, Marc J., and Donald A. Carpenter. A heuristic job scheduling decision support system A case study, Decision Support Systems 18, 2, 159-166, (1996).
[12] Strohhecker, Jürgen, Michael Hamann, and Jörn-Henrik Thun. Loading and sequencing heuristics for job sched-uling on two unrelated parallel machines with long, sequence-dependent set-up times. International Journal of Production Research 54, 22, 6747-6767, (2016).
[13] Fuchigami, Helio Yochihiro, and Socorro Rangel. A survey of case studies in production scheduling: Analysis and perspectives, Journal of Computational Science 25, 425-436, (2018).
[14] Abu-Shams, Mohammad, et al. Scheduling Large-Size Identical Parallel Machines with Single Server Using a Novel Heuristic-Guided Genetic Algorithm (DAS/GA) Approach, Processes 10,10, 2071, (2022).
[15] Eroğlu, Duygu Yilmaz, H. Cenk Özmutlu, and Seyit Ali Köksal. A Genetic Algorithm for The Unrelated Parallel Machine Scheduling Problem with Job Splitting and Sequence-Dependent Setup Times-Loom Scheduling, Textile and Apparel 24,1 66-73, (2014).
[16] Potts, Chris N. Analysis of heuristics for two-machine flow-shop sequencing subject to release dates, Mathematics of Operations research 10, 4, 576-584, (1985).
[17] Montoya-Torres, Jairo R., Milton Soto-Ferrari, and Fernando Gonzalez-Solano. Production scheduling with se-quence-dependent setups and job release times, Dyna 77, 163, 260-269, (2010).
[18] Zhang, Fangfang, et al. Multitask genetic programming-based generative hyperheuristics: A case study in dynamic scheduling, IEEE Transactions on Cybernetics, (2021).
[19] Framinan, Jose M., Jatinder ND Gupta, and Rainer Leisten. A review and classification of heuristics for permu-tation flow-shop scheduling with makespan objective, Journal of the Operational Research Society 55, 12, 1243-1255, (2004).
[20] Allahverdi, Ali, Jatinder ND Gupta, and Tariq Aldowaisan. A review of scheduling research involving setup considerations, Omega 27, 2, 219-239, (1999).
[21] Dhingra, A., and Chandna, P. M-machine SDST flow shop scheduling using modified heuristic genetic al-gorithm, International Journal of Engineering, Science and Technology, 2(5), 216-225, (2010).
[22] Yong, Liao, et al. Heuristics for the Hybrid Flow Shop Scheduling Problem with Sequence-Dependent Setup times. Mathematical Problems in Engineering (2022).
[23] Balo, Habtamu Tesfaye. Optimization of Job Shop Scheduling Problem, Journal of Mechanical, Civil and Industrial Engineering 1,1, 14-20, (2020).
[24] Deeratanasrikul, Lalida, and Shinji Mizuno. Multiple-stage multiple-machine capacitated lot-sizing and sched-uling with sequence-dependent setup: A case study in the wheel industry, Journal of Industrial and Management Optimization 13,1, 413, (2017).
[25] Dalfard, V. M., and Mohammadi, G. Two meta-heuristic algorithms for solving multi-objective flexible job-shop scheduling with parallel machine and maintenance constraints, Computers and Mathematics with Applica-tions, 64, 6, 2111-2117, (2012).
[26] Caicedo-Rolón Junior, Á., and Llanos, J. W. P. Production sequencing in a flow shop system using optimization and heuristic algorithms. Gestão and Produção, 28, (2021).
[27] MacCarthy, B. L., and Jou, P. A case-based expert system for scheduling problems with sequence dependent set up times, WIT Transactions on Information and Communication Technologies, 10, (1970).
[28] Koulamas, C. The total tardiness problem: review and extensions, Operations research, 42, 6, 1025-1041, (1994).
[29] Baker, K. R., and Altheimer, D. Heuristic solution methods for the stochastic flow shop problem, European Journal of Operational Research, 216, 1, 172-177, (2012).
[30] Daneshdoost, F., Hajiaghaei-Keshteli, M., Sahin, R., and Niroomand, S. Tabu Search Based Hybrid Me-ta-Heuristic Approaches for Schedule-Based Production Cost Minimization Problem for the Case of Cable Manu-facturing Systems, Informatica, 1-24, (2022).
[31] Lin, S. W., and Ying, K. C. Single machine scheduling problems with sequence-dependent setup times and precedence delays. Scientific Reports, 12, 1, 1-12, (2022).
[32] Abiri, M. B., Zandieh, M., and Alem-Tabri, A. A tabu search approach to hybrid flow shops scheduling with sequence-dependent setup times, Journal of applied sciences, 9, 9, 1740-1745, (2009).
[33] Sari, Y. A., and Kumral, M. An improved meta-heuristic approach to extraction sequencing and block rout-ing, Journal of the Southern African Institute of Mining and Metallurgy, 116, 7, 673-680, (2016).

[34] Rabani, M., Aghamohamadi, S., and Yazdanparast, R. Optimization of parallel machine scheduling problem with human resiliency engineering: A new hybrid meta-heuristics approach, Journal of Industrial and Systems En-gineering, 12, 2, 31-45, (2019).
[35] Baker, K. R. Heuristic procedures for scheduling job families with setups and due dates. Naval Research Logistics (NRL), 46, 8, 978-991, (1999).
[36] Mohamad, N. H., and Said, F. Solving single machine scheduling problem with common due date. Business Management Dynamics, 1, 4, 63, (2011).
[37] Muthukumaran, M., and Muthu, S. A heuristic scheduling algorithm for minimizing makespan and idle time in a Nagare cell, Advances in Mechanical Engineering, 4, 895463, (2012).
[38] Senthilkumar, P., and Narayanan, S. Literature review of single machine scheduling problem with uniform parallel machines, (2010).
[39] Hadri, A., Smadi, H., and Belkaid, F. An Effective Approach for Solving a Job Shop Problem under Com-ponents Consumption and Unidirectional Transport Constraints: A Case Study, Academic Journal of Manufacturing Engineering, 20, 1, (2022).
[40] Yu, Y., Lu, X., Zhao, T., Cheng, M., Liu, L., and Wei, W. Heuristic Approaches with Reinforced Parameter Tuning for the Car Sequencing Problems with Block Batches, (2021).
[41] Crauwels, H. A. J., Potts, C. N., and Van Wassenhove, L. N. Local search heuristics for single-machine scheduling with batching to minimize the number of late jobs, European Journal of Operational Research, 90, 2, 200-213, (1996).
[42] Hossain, M. S., Asadujjaman, M., Nayon, M. A., and Bhattacharya, P. Minimization of makespan in flow shop scheduling using heuristics. In International Conference on Mechanical, Industrial and Energy Engineering, (2014).
[43] Agarwal, A. K., and Garg, R. Flowshop Scheduling Problem for 10-Jobs, 10-Machines by Heuristics Models Using Makespan Criterion, International Journal of Innovations in Engineering and Technology (IJIET), 2, 1, 2319-1058, (2013).
[44] Mansourifard, F., Mansourifard, P., Ziyadi, M., and Krishnamachari, B. A heuristic policy for outpatient surgery appointment sequencing: newsvendor ordering, In 2nd IEOM European Conference on Industrial Engineering and Operations Management, Paris, (2018).
[45] Wong, T. C., Xu, M., and Chin, K. S. A two-stage heuristic approach for nurse scheduling problem: A case study in an emergency department, Computers and Operations Research, 51, 99-110, (2014).
[46] Lapczynska, D., Lapczynski, K., Burduk, A., and Machado, J. Solving the problem of scheduling the pro-duction process based on heuristic algorithms, Journal of Universal Computer Science, 28, 3, 292-310, (2022).
[47] Koch, C., Arbaoui, T., Ouazene, Y., Yalaoui, F., De Brunier, H., Jaunet, N., and De Wulf, A. A matheuristic approach for solving a simultaneous lot sizing and scheduling problem with client prioritization in tire industry, Computers and Industrial Engineering, 165, 107932, (2022).
[48] Rodrigues, R., Pessoa, A., Uchoa, E., and Poggi de Aragão, M. Heuristic algorithm for the parallel machine total weighted tardiness scheduling problem, Relatório de Pesquisa em Engenharia de Produçao, 8, 10, 1-11, (2008).
[49] Direkli, M. A Heuristic Approach on Flexible Job-Shop Scheduling Problem with Maintenance Activities by Con-sidering Weight of the Jobs (Master's thesis, Fen Bilimleri Enstitüsü), (2015).
[50] Mula, J., Díaz-Madroñero, M., Andres, B., Poler, R., and Sanchis, R. A capacitated lot-sizing model with sequence-dependent setups, parallel machines and bi-part injection moulding, Applied Mathematical Modelling, 100, 805-820., (2021).
[51] Birgin, E. G., and Ronconi, D. P. Heuristic methods for the single machine scheduling problem with different ready times and a common due date, Engineering Optimization, 44, 10, 1197-1208, (2012).
[52] Siraj, H., and Bareduan, S. A. Initial Sequence Strategy for Constructive Heuristics Using Gantt Chart, Research Progress in Mechanical and Manufacturing Engineering, 3,1, 87-96, (2022).
[53] Perez-Gonzalez, P., Fernandez-Viagas, V., García, M. Z., and Framinan, J. M. Constructive heuristics for the unrelated parallel machines scheduling problem with machine eligibility and setup times, Computers and Industrial Engineering, 131, 131-145, (2019).
[54] Johnson, Selmer Martin. Optimal two-and three-stage production schedules with setup times included, Naval research logistics quarterly 1,1, 61-68, (1954).
[55] Das, M. K. Selected heuristic algorithms for solving job shop and flow shop scheduling problems (Doctoral dis-sertation), (2014).
[56] Gavrilas, Mihai. Heuristic and metaheuristic optimization techniques with application to power sys-tems, Technical University of Iasi, D. Manger on Blvd., Iasi, Romania, (2010).

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