University of Benghazi
Faculty of Education Almarj

جامعة بنغازي
كلية التربية – المرج
ISSN 2518-5845

Global Libyan Journal

المجلة الليبية العالمية

العدد التاسع والأربعون / أكتوبر / 2020

Solve no –wait job shop scheduling problem using a local search algorithm

Mohammad Mahmoud Hamed. Department of industrial and Manufacturing

University of Benghazi
Faculty of Education Almarj

جامعة بنغازي
كلية التربية – المرج
ISSN 2518-5845

Global Libyan Journal
المجلة الليبية العالمية

العدد التاسع والأربعون / أكتوبر / 2020

Solve no –wait job shop scheduling problem using a local search algorithm

1.Abstract:

In this paper, no-wait job shop problems with makespan minimization are considered. It is well known that these problems are strongly NP-hard. The problem is decomposed into the sequencing and the timetabling components. The results showed that the new PNS method gives less makespan value with different problems size (15x15, 20x15, 20x20, 30x15, 30x20, 50x15, 50x20 and 100x20) taken from the OR- library compared to previous well known neighborhood search methods. In independent setup times we compared the result with the best solution from OR- library, and have been results indicates the proposed neighborhood search structure near from best solution compare with other methods of NS.

Key word: Job shop scheduling, Sequence-independent setup times (no wait), local search, neighborhood search structure, makespan.

الملخص:

في هذه الورقة ، يتم النظر في مشاكل الجدولة بدون انتظار مع تقليل وقت الانهاء الكلي. ومن المعروف أن هذه المشاكل تعتبرمن المشاكل المعقدة في الحل وعند زيادة عدد من الالات او الشغلات يزداد عدد الحلول الممكنه بشكل غير منظم وتسمي (NP hard problem). أوضحت النتائج أن طريقة الجار الجديده PNS تعطي قيمة أقل وقت انتهاء لكل الشغلات مع مشاكل مختلفة الحجم عدد الشغلات *عدد الالات (15 × 15 ، 20 × 15 ، 20 × 20 ، 30 × 15 ، 30 × 20 ، 50 × 15 ، 50 × 20 ، 100 × 20) مأخوذة من مكتبة OR مقارنة بطرق البحث السابقة المعروفة. في الوقت الكلي لانتهاء الشغلات ، قارنا النتيجة بأفضل حل من مكتبة OR، وكانت النتائج تشير إلى بنية البحث PNS المقترحة تقترب من أفضل الحلول مقارنة بالطرق الأخرى لـ NS.

2.An Introduction

In this paper, the no-wait job shop with makespan minimization is considered, in which consecutive operations of each job must be performed continuously without any interruption. No wait constraints usually arise from requirements for processing environments or characteristics of jobs. Typical examples are iron being immediately stanched while hot in metallurgical processes and unstable intermediate products or absence of intermediate storage capacity in chemical processes.

3. Literature review

[4]: provided an extensive review of the scheduling literature on models with setup times (costs) from then to date covering more than 300 papers. Scheduling problems are classified into those with batching and non-batching considerations, and with sequence-independent and sequence-dependent setup times, and are categorized according to shop environments, including single machine, parallel machines, flow shop, no-wait flow shop, flexible flow shop, job shop, open shop, and others.

[14]: proposed a mathematical model which presents a good performance to obtain feasible solutions. The mathematical model is unable to reach the optimum results in larger problems. Thus, they developed a heuristic model based on priority rules, Because of the inability to find optimum solutions in reasonable computational times, and 3 different innovative lower, which could be implemented to evaluate different heuristics and meta-heuristics in larger problems. The performance of the heuristic model evaluated with a well-known example in the literature insures that the model seems to have a strong ability to solve job shop scheduling with sequence dependent setup times problems and to obtain good solutions in reasonable computational times.

[5]: investigated scheduling job shop problems with sequence-dependent setup times under minimization of makespan. They developed an effective meta-heuristic, simulated annealing with novel operators, to potentially solve the problem. They proposed an effective neighborhood search structure based on insertion neighborhoods as well as analyzing the behavior of simulated annealing with different types of operators and parameters by the means of Taguchi method. An experiment based on Taillard benchmark is conducted to evaluate the proposed algorithm against some effective algorithms. The results showed that the proposed algorithm outperforms the other algorithms.

[3]: proposed a new method for solving job-shop scheduling problem using hybrid Genetic Algorithm (GA) with Simulated Annealing (SA). This method introduces a reasonable combination of local search and global search for solving JSSP.

[12]: used simulated annealing algorithm for multi-objective flexible job shop scheduling problem with overlapping in operations to find a suitable solution. To evaluate performance

of the algorithm, a mixed integer linear programming Model is developed, and solved it with the classical method (branch and bound). The results showed that in small size problems, the solutions of the proposed algorithm and the mathematical model were so close, and in medium size problems, they only had lower and upper bounds of solution and our proposed algorithm had a suitable solution. Also, they used total machine work loading time and critical machine work loading time as evaluation criteria.

[2]: considered flexible job-shop scheduling problem (FJSP) with sequence-dependent setup times to minimize makespan and mean tardiness. Neighborhood structures related to the sequencing problem and the assignment problem were employed to generate neighboring solutions. To evaluate the performance of the proposed algorithm, 20 test problems in different sizes are randomly generated.

[15]: proposed a mixed integer linear programming model which includes process planning and scheduling tasks simultaneously in a flexible assembly job shop with sequence dependent setup times. The objective function is minimizing maximum completion time (makespan) of final products. Also, in order to exploit the maximum flexibility in the shop floor for process planning and scheduling tasks, identical parts have been considered as distinct parts. Finally, several hypothetical test problems have been solved to show the merit of the proposed mathematical model.

[13]: considered a dynamic flexible job shop scheduling in which there are sequence-dependent setup times and machines are prone to failure. They proposed three new routing rules, and compared them with another two rules from the literature through simulation experiments.

[9]: considered job shop scheduling with sequence-dependent setups in which jobs are grouped into job families, but they are processed individually. This type of job shop scheduling can be found in various manufacturing systems, especially in remanufacturing systems with disassembly, reprocessing and reassembly shops. To minimize the deviations of the job completion times within each job family, the objective of minimizing the total family flow time. A mixed integer programming model is suggested, and then, due to the complexity

of the problem, a heuristic algorithm is suggested. Computational experiments were done on small-sized test instances.

[11]: presented a new multi-objective job shop scheduling hybrid genetic algorithm (HGA) with sequence-dependent setup times. The objectives are to minimize the makespan and sum of the earliness and tardiness of jobs in a time window. To validate the efficiency of our proposed HGA, a number of test problems are solved.

[10]: in this paper addresses the classic job shop scheduling where sequence dependent setup times. Used a tabu search algorithm with a sophisticated neighborhood structure for solve this problem. Based on modified disjunctive graph, he further investigates and generalizes structural properties for the problem under study.

[1]: this paper presents the implementation of a scheduling algorithm in a hot rolling mill, which features several reheating furnaces and which is characterized by bidirectional material flow, blocking, and no-wait constraints. The scheduling problem is solved by a decomposition into a timetabling algorithm and a sequence optimization procedure. For the timetabling task, where the sequence of products is assumed to be fixed, a new recursive algorithm to generate a non-delay feasible schedule is developed. The sequence optimization procedure searches for the optimum product sequence and makes heavy use of the timetabling algorithm. A competitive starting sequence is

4.Steps of local search algorithm (LS):

1. Encoding schemes.

Encoding schemes are used to make a candidate solution recognizable for algorithms. A proper encoding scheme plays a key role in maintaining the search effectiveness of any algorithms. To evaluate the degree of sensitivity (robustness) of our LS on its initial solution (IS), we bring the choice of IS into the calibration section and compare the performance of two SAs starting from a random generated IS and from any methods for example shortest processing time (SPT).

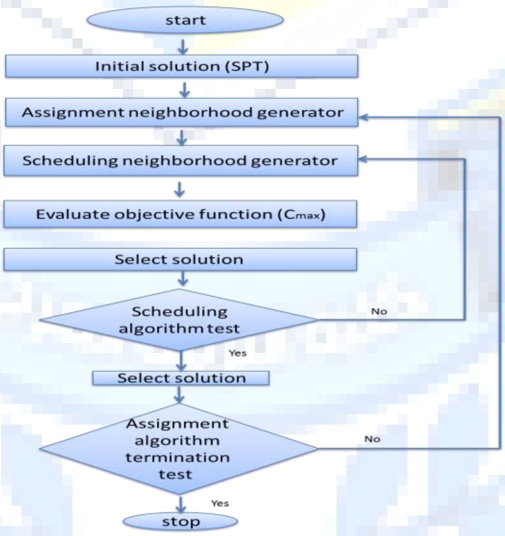
2. Neighborhood search structure (NSS).

Neighborhood search structure generates a new solution from current candidate solution by making a slight change in it. foure different NSSs are considered:

SWAP, *SHIFT*, INVERSION *and Migration Mechanism*. *The proposed neighborhood search structure* (PNS) is implemented in two steps; the first step is to generate a random number to cut the sequence at a random position. So, the sequence is splinted into a tail part. Then, the tail part is inverted and replaced by the head part. And the head part is replaced at the tail part. The best generated farther neighbor is accepted to move, whether it has the better objective function than the current solution or not. In the example above select random number e.g in the first step select cut point 3, then inverted and replaced by the head part, new sequence is j5, j4, j3, j1 and j2.

The local search algorithm generates an initial solution using shortest processing time method and then neighborhood of this solution and afterward compares objective functions of them with each other: if the new solution is better than the current solution, it substitutes current solution with the new solution and then generates another neighborhood.

Figure (1): Solution approach SA algorithm flowchart.



5.Experimental design

A set of benchmark problems is generated based on Taillard's instances. Data required for a problem consist of the number of jobs (n), number of machines (m), range of processing times (p). The benchmark contains different combinations of the number of jobs n and the number of machines m. The (n, m) combinations are: ({20, 30 and 50}. (15, 20), (15 x 15) and (100 x 20) summing up 8 combinations of (n x m). The algorithm is coded in C# and run on a PC with 2.50 GHz Intel Core (TM) i5 and 4 GB of RAM.

6.Assumptions:

1. Each job has its own processing route; that is, jobs visit machines in different orders.
2. Each job might need to be performed only on a fraction of m machines, not all of them.
3. Each job can be processed by at most one machine at a time and each machine can process at most one job at a time. When the process of an operation starts, it cannot be interrupted before the completion; that is, the jobs are non-preemptive.
4. The jobs are independent; that is, there are no precedence constraints among the jobs and they can be operated in any sequence.
5. The jobs are available for their process at time 0.
6. There is no machine breakdown (i.e. Machines are continuously available).
7. The sequences of jobs in machines are independent setup times, $S_{ij} = 0$.
8. The objective function when solving or optimizing a JSS is to determine the processing order of all jobs on each machine that minimizes the makespan.

The number of iterations varies depending on the size of the problem; the greater the size of the problem has increased the number of iterations. In this table, shown how the number of iterations increases with the size of the problems.

Table (1): Number of iterations which give the best solution.

Problems size (nxm)	15x15	20x15	20x20	30x15	30x20	50x15	50x20	100x20
Number of iterations	500	600	800	1000	1200	2500	2500	5000

Figure (2): Number of iterations which give the best solution.

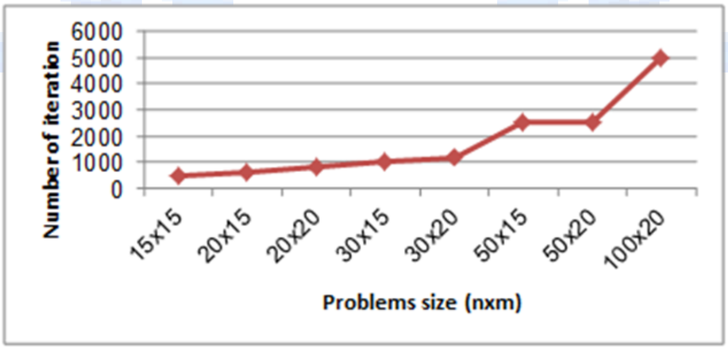
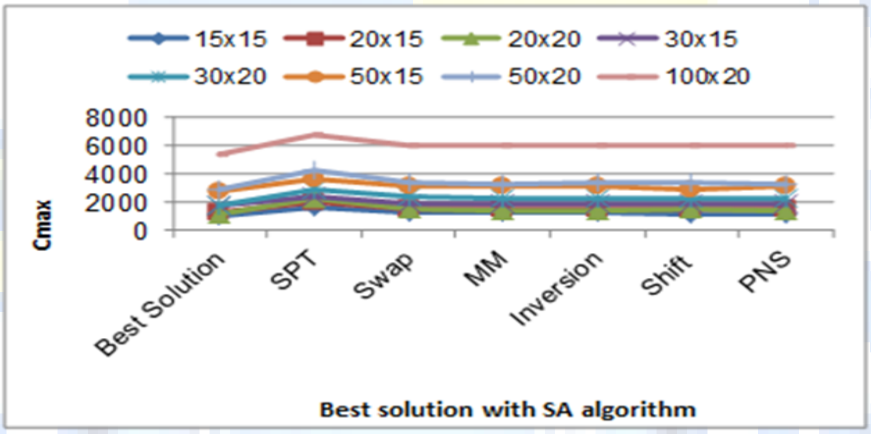


Table (2) solves the job shop scheduling problem with independent setup times or setup times equal zero. We compared the best solution from the OR- library Taillard's with local search method using five methods neighborhood search structure.

Table (2): solve JSSP independent setup times with different NSS.

Problems size (nxm)	**Best Solution**	**Initial Solution SPT**	**Local search Algorithm with def. NS (LSNSS)**				
			Swap	**MM**	**Inversion**	**Shift**	**PNS**
15x15	1005	1644	1310	1330	1250	1214	1205
20x15	1254	2000	1597	1597	1597	1575	1510
20x20	1217	2359	1542	1470	1430	1490	1376
30x15	1764	2474	1932	1932	1910	1932	1900
30x20	1850	2910	2400	2310	2300	2310	2300
50x15	2760	3621	3198	3110	3124	2924	3124
50x20	2868	4282	3381	3301	3381	3381	3341
100x20	5464	6754	6086	6086	6086	6086	6086

Figure (3): JSSP independent setup times with different NSS.



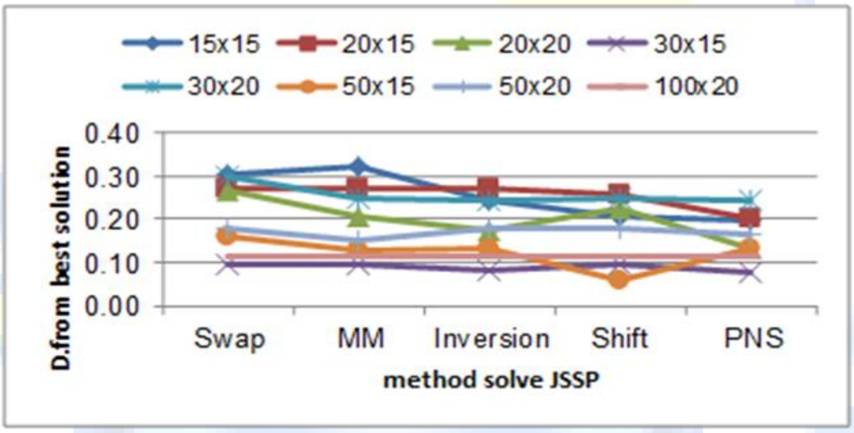
Has been calculated the deviation from best solution by this equation $\frac{(NSC_{\max} - bsC_{\max})}{bsC_{\max}}$.

Table (3) explains extent of deviation between best solution and method LSNS (Swap, inversion, MM, Shift and PNS).

Table (3): Deviation proposed SA algorithm about best solution.

Problems size (n x m)	The deviation about best solution				
	Swap	MM	Inversion	Shift	PNS
15x15	0.30	0.32	0.24	0.21	0.20
20x15	0.27	0.27	0.27	0.26	0.20
20x20	0.27	0.21	0.18	0.22	0.13
30x15	0.10	0.10	0.08	0.10	0.08
30x20	0.30	0.25	0.24	0.25	0.24
50x15	0.16	0.13	0.13	0.06	0.13
50x20	0.18	0.15	0.18	0.18	0.16
100x20	0.11	0.11	0.11	0.11	0.11

Figure (4): Deviation proposed SA algorithm about best solution.



7. Conclusion

In this study examined job shop scheduling with the sequence in independent setup times. The optimization criterion is makespan. To tackle the problem we apply meta-heuristic, in the framework of local search, by studying the effect of a novel neighborhood search structure. The numerical experiment included a set of instances generated based on Taillard's benchmark. Were compared four types of neighborhood search structure with proposed NSS, And the results show that the PNS method outperformed the other neighborhood methods taken from the literature. In independent setup times we compared the result with the best solution from or- library, and have been results indicates the proposed neighborhood search structure nearer from best solution compare with other methods of NS.

References

[1]:A. Aschauer, F. Roetzer, A. Steinboeck, A Kugi" **An Efficient Algorithm for Scheduling a Flexible Job Shop with Blocking and No-Wait Constraint** FAC Papers OnLine 50-1 12490–12495 2017.

[2]:A.Bagheria, and M. Zandiehb, " **Bi-criteria flexible job-shop scheduling with sequence-dependent setup times—Variable neighborhood search approach**" Journal of Manufacturing Systems 30 (2011) 8–15.

[3]:A.Tamilarasi and T. Anantha kumar "**An enhanced genetic algorithm with simulated annealing for job-shop scheduling**" International Journal of Engineering, Science and Technology, Vol. 2, No. 1, 2010, pp. 144-151.

[4]:Ali Allahverdi, C.T. Ng, T.C.E. Cheng, and Mikhail Y. Kovalyov "**A survey of scheduling problems with setup times or costs**", European Journal of Operational Research 187 (2008) 985–1032.

[5]:B. Naderi, S.M.T. Fatemi Ghomi, and M. Aminnayeri " **A high performing metaheuristic for job shop scheduling with sequence-dependent setup times**", Applied Soft Computing 10 (2010) 703–710.

[6]:Cemal Ozguven, Yasemin Yavuz, and Lale Ozbakır ,"**Mixed integer goal programming models for the flexible job-shop scheduling problems with separable and non-separable sequence dependent setup times**", Applied Mathematical Modelling , volume 36 (2012) 846–858.

[7]:Daniel sipper and Robert L. Bulfin "**production planning, control and integration**", McGraw-Hill, 1998.

[8]:Garey, Michael R.; Johnson, David S.and A W. H. Freeman**, "Guide to the Theory of NP-Completeness"**. Computers and Intractability ISBN 0-7167-1045-5 (1979).

[9]:Jung-Hyeon Park, and Dong-Ho Lee " **Job Shop Scheduling with Job Families and Sequence dependent Setups: Minimizing the Total Family Flow Time**" Proceedings of the Asia Pacific Industrial Engineering & Management Systems Conference 2012.

[10]:Liji Shen **"atabu search algorithm for the job shop scheduling problem with sequence dependent setup time"** computer and industrial engineering, reference CAIE 3796. 2 September 2014.

[11]:M. B. Fakhrzad, A. Sadeghieh, and L. Emami "**A New Multi-objective Job Shop Scheduling with Setup Times Using a Hybrid Genetic Algorithm**", IJE TRANSACTIONS B: Applications Vol. 26, No. 2, (February 2013) 207-218.

[12]:Mehrzad Abdi Khalife, Babak Abbasi, and Amir Hossein Kamali Dolat Abadia " **A Simulated Annealing Algorithm for Multi Objective Flexible Job Shop Scheduling with Overlapping in Operations** "Journal of Industrial Engineering, volume 5(2010) 17-28.

[13]:Mohamed A. Shalaby , Tamer F. Abdelmaguid, and Zakaria Y. Abdelrasol "**New Routing Rules for Dynamic Flexible Job Shop Scheduling with Sequence-Dependent Setup Times**", Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management, Istanbul, Turkey, July 3 – 6, 2012.

[14]:R. Moghaddas , and M.Houshmand "**Job-Shop Scheduling Problem With Sequence Dependent Setup Times**" Proceedings of the International MultiConference of Engineers and Computer Scientists 2008 Vol II, IMECS 2008, 19-21 March, 2008, Hong Kong.

[15]:Saeid Nourali , Narges Imanipour, and Mohammad Reza Shahriari "**A Mathematical Model for Integrated Process Planning and Scheduling in Flexible Assembly Job Shop Environment with Sequence Dependent Setup Times**", Int. Journal of Math. Analysis, Vol. 6, 2012, no. 43, 2117 – 2132.

[16]:Sultana Parveen* and Hafiz Ullah "**Review on Job-Shop and Flow-Shop Scheduling using Multi Criteria Decision Making**"Journal of Mechanical Engineering, Vol. ME 41, No. 2, December 2010.Transaction of the Mech. Eng. Div., The Institution of Engineers, Bangladesh.

[17]:Taillard," **Benchmarks for basic scheduling problems**", European Journal of Operational Research 64 (1993) 278–285.

[18]:Xiaoqing sun, and James S. Noble "**An approach to job shop scheduling with sequence dependent setups**", Journal of manufacturing systems, volume 18, No; 6, 1999.