Integration of transportation resources in the flexible job-shop scheduling problem

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1 Introduction and literature review

Many extensions of the job-shop scheduling problems have been studied in the literature in the past years. This paper discusses a combination of two extensions of the job-shop scheduling problem : the flexible job-shop scheduling problem (FJSP), where multiple machines can perform the same production operation, and the job-shop scheduling problem with transportation resources where a fleet of vehicles must perform transportation tasks between machines. The flexible job-shop problem with transportation resources (FJSPT) involves the assignment of production and operations to machines or vehicles, the scheduling of production operations on machines and vehicle routing. We use a disjunctive graph model to quickly evaluate every possible move in a local search algorithm.

The FJSPT has been introduced simultaneously by [3] and [4]. Both teams proposed a benchmark from the instances of [1].

2 Problem definition

The defined problem is an extension of the FJSP where transport resources are explicitly considered. The problem is composed of a set of jobs, which are a sequence of multiple consecutive operations, a set of machines and a set of vehicles with unit capacity. As it is an extension of the FJSP, each production operation has a set of machines on which it can be processed. Processing times of the production operations are machine dependent while vehicle travel times are not vehicle dependent.

The objective is to determine an assignment of production operations to machines, an assignment of transportation operations to vehicles, and schedule both sequences of transport and production operations in order to minimize the makespan C_{max} (time of completion of all jobs).

We adapt a tabu search method first introduced in [2] for the FJSP, then extended to the flexible job-shop with sequence-dependent setup times with a new neighborhood structure in [5], using disjunctive graph modeling with a new definition of moves. The disjunctive graph modeling is used to quickly evaluate the moves .

3 Modeling and solution method

The disjunctive graph is given by $G = (V, E_c, E_d)$, where V denotes the set of nodes of G, E_c the set of conjunctive arcs and E_d the set of disjunctive arcs. A node $v \in V$ represents an operation of a job. The initial conjunctive arcs, defined as directed arcs, represent precedence constraints between operations in a job. The disjunctive arcs, defined as undirected arcs, represent the need to schedule on one machine one node at one end before the other.

Once this graph is built, a possible schedule can be determined by finding, for each machine, a chain of oriented arcs from the disjunctive arcs. The conjunctive graph is a solution to the scheduling problem if there is no cycle. Each precedence constraint is represented. The makespan is the longest path from the initial dummy node 0, linked with all the first operations of the jobs, to the final dummy node $*$, linked with all the final operations of the jobs.

We exploit a tabu search procedure to perform moves among those that do not create a cycle and use a quick upper/lower bound evaluation of moves to select a promising move. Evaluating a move of a transportation operation only implies to evaluate the four potential critical paths created after the move while evaluating a move of a reassigned production operation is more complex as reassigning a production operation also change the travel times of related transportation operations.

4 Conclusions

In this extended abstract, we have addressed a complex flexible job shop problem with transportation resources motivated by the semiconductor manufacturing industry. Additional details on the proposed disjunctive graph for the modeling of the problem will be described. Furthermore, the results obtained on the experiments we have conducted on existing benchmarks will be presented.

Références

[1] Ümit Bilge and Gündüz Ulusoy. A time window approach to simultaneous scheduling of machines and material handling system in an fms. *Operations Research*, 43(6) :1058–1070, 1995.

[2] Stéphane Dauzère-Pérès and Jan Paulli. An integrated approach for modeling and solving the general multiprocessor job-shop scheduling problem using tabu search. *Annals of Operations Research*, 70 :281–306, 1997.

[3] L Deroussi and S Norre. Simultaneous scheduling of machines and vehicles for the flexible job shop problem. In *International conference on metaheuristics and nature inspired computing*, pages 1–2. Djerba Island Tunisia, 2010.

[4] MV Kumar, Ranga Janardhana, and CSP Rao. Simultaneous scheduling of machines and vehicles in an fms environment with alternative routing. *The International Journal of Advanced Manufacturing Technology*, 53(1) :339–351, 2011.

[5] Liji Shen, Stéphane Dauzère-Pérès, and Janis S Neufeld. Solving the flexible job shop scheduling problem with sequence-dependent setup times. *European Journal of Operational Research*, 265(2) :503–516, 2018.