

## Chapter 9

# A Hybrid Meta-Heuristic to Solve a Multi- Criteria HFS Problem

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### ABSTRACT

*In this chapter the authors address a hybrid flow shop scheduling problem considering the minimization of the makespan in addition to the sum of earliness and tardiness penalties. This problem is proven to be NP-hard, and consequently the development of heuristic and meta-heuristic approaches to solve it is well justified. So, to deal with this problem, the authors propose a method which consists on the one hand, on using a meta-heuristic based on ant colony optimization algorithm to generate feasible solutions and, on the other hand, on using an aggregation multi-criteria method based on fuzzy logic to assist the decision-maker to express his preferences according to the considered objective functions. The aggregation method uses the Choquet integral. This latter allows to take into account the interactions between the different criteria. Experiments based on randomly generated instances were conducted to test the effectiveness of the approach.*

### INTRODUCTION

Scheduling problems are encountered at all levels and in all sectors of activity. Most scheduling problems are very difficult to solve ((Blazewicz, Ecker, Pesch, & Schmidt, 1996)and (Graham,

Lawler, & Rinnooy Kan, 1979)). That's why the majority of the problems addressed in scheduling are only evaluated by a single criterion (such as makespan, total tardiness, workloads of machines, etc) (T'kindt & Billaut, 2002). However, in the literature, many researches in scheduling show

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that the majority of combinatorial optimization problems and especially the industrial ones involve generally simultaneous incommensurable criteria, which they can sometimes be contradictory. The combining of several criteria induces additional complexity. Optimizing multi-criteria problems seeks to optimize several components of a vector cost function (Talbi, 1999). Unlike single criterion optimization problems, there is no single optimal solution for multi-criteria problems, but a set of compromises solutions, known as Pareto-optimal solutions. These solutions are optimal in the wider sense that no other solutions in search space are superior to them when all criteria are considered (Zitzler & Thiele, 1999).

The hybrid flow shop (HFS), also called multiprocessor or flow shop with parallel machines, consists of a set of two or more processing stages (or centers) with at least one stage having two or more parallel machines. The hybrid characteristic of a flow shop is ubiquitously found in various industries. The duplication of the number of machines in some stages can introduce additional flexibility, increase the overall capacities, and avoid bottlenecks if some operations are too long. So, scheduling in HFS has a great importance from both theoretical and practical view points.

The main goal of this chapter is to present a solution methodology for solving a multi-criteria HFS problem. The considered objective is to simultaneously minimize the following criteria:

1. Minimize the completion date of all the jobs (makespan),
2. Minimize the weighted sum of the earliness and tardiness (ET) penalties.

The ET problem encompasses a category of problems with the objective to complete each job as close to its due date possible. It represents a non-regular optimization criteria based on due dates (Gupta, Krüger, Lauff, Werner, & Sotskov, 2002). This objective represents just in time (JIT) production concept (Portmann & Mouloua, 2007).

In fact, in a JIT environment, minimizing earliness would reduce inventory costs and/or deterioration of product while minimizing tardiness would reduce a late cost or the loss of customers. In this scenario both early and tardy completion of jobs is disadvantageous to manufacturers and customers. Each job has a distinct earliness or tardiness penalty weight, which represents the importance of a job production system. This multi-criteria scheduling problem is NP-hard since the simpler mono-criterion HFS problem, made up of two stages and having at least two machines available in one of the stages, with makespan criterion is already NP-hard (Gupta, 1988). In addition, earliness/tardiness criteria, with distinct due dates, usually induce NP-hard problems (Hendel & Sourd, 2007). Therefore, the development of heuristics that can give eventually optimal or near optimal solutions is well justified. For solving scheduling problem, various intelligent heuristics and meta-heuristics have become popular such as simulated annealing (SA), tabu search (TS), multi-agent system (MAS), genetic algorithm (GA) and ant colony optimization algorithm (ACO). The literature for HFS problem has adopted regular measures of performance, mainly the makespan, the sum of completion time, the tardiness. However, most of the articles that tackle ET problems deal with single machine ((Merkle & Middendorf, 2005), (M'Hallah, 2007) and (Valente & Alves, 2007)). Also, many results exist for parallel machine earliness/tardiness scheduling problems, especially when all jobs have the same due date ((Balakrishnan, Kanet, & Sridharan, 1999) and (Ventura & Kim, 2003)). However, relatively little researches have considered the ET costs in the objective function on flow and job shop environments. So, Rajendran and Alicke (Rajendran & Alicke, 2007) developed some dispatching rules to solve the flow shop ET problem with bottleneck machines. In (Valencia & Rabadi, 2003) the authors proposed a MAS approach to solve the job shop ET problem with common due date. For the job shop ET problem

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