

# Chapter 14

## Multicriteria Flow Shop Scheduling Problem

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### ABSTRACT

*Quality is, in real-life, a multidimensional notion. A schedule is described and valued on the basis of a number of criteria, for example: makespan, work-in-process inventories, idle times, observance of due dates, etc. An appropriate schedule cannot be obtained unless one observes the whole set of important criteria. The multidimensional nature of the scheduling problems leads us to the area of Multicriteria Optimization. Thus considering combinatorial problems with more than one criterion is more relevant in the context of real-life scheduling problems. Research in this important field has been scarce when compared to research in single-criterion scheduling. Until the late 1980's, only one criterion was considered in scheduling problems. Furthermore, until the 1990's, most work in the area of multiple criteria scheduling consists of bi-criteria studies of the single machine case. The proliferation of metaheuristic techniques has encouraged researchers to apply them to combinatorial optimization problems. The aim of this chapter is to present a review regarding multicriteria flow-shop scheduling problem, focusing on Multi-Objective Combinatorial Optimization theory, including recent developments considering more than one optimization criterion, followed by a summary discussion on research directions.*

### INTRODUCTION

In this chapter, we consider a scheduling problem for which, after more than 50 years of scientific research, there is an important gap between theory and practice. Flow-shop problem results in several

contexts, where machines are used to represent the resources and different operations must be carried out with them. So, the aim is to find the schedule that optimizes certain performance measures. To the complexity that naturally arises in these problems, considering only one criterion (Garey & Johnson, 1979), we have to add the additional complexity that comes from the mul-

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tvariant condition of corresponding alternative schedules. In fact the description and valuation of alternative decisions are not naturally accomplished by only one criterion, but by several (*e.g.* makespan, flow-time, completion-time, tardiness, inventory, utilization, etc.). This is certainly the natural framework of the Multicriteria Decision Making discipline (MDM). A solution which is optimal with respect to a given criterion might be a poor candidate for another. The trade-offs involved in considering several different criteria provide useful insights for the decision-maker. Thus considering Combinatorial Optimization (CO) problems with more than one criterion is more relevant in the context of real-life scheduling problems.

Most of the multicriterion approaches applied to scheduling problems are based on Multi-Objective Optimization (MOO) models. Of course, to expect to find the “Optimum” schedule must usually be discarded. We would be satisfied to find the set of non-dominated, also called Pareto optimal, alternatives. At this point, we have to let some subjective considerations intervene, such as the decision-maker preferences. It is actually an MDM problem, and at the present time, there is no other rational tool to apply to discard alternatives. MOO was originally conceived to find a set of Pareto optimal alternative solutions. Only with the breakthrough of metaheuristics in solving CO problems, did researchers begin to adapt them to solve Multi-Objective Combinatorial Optimization problems. Then, the acronym MOCO started to appear in the scientific literature together with the techniques developed to deal with them. Research in this important field has been scarce when compared to research in single-criterion scheduling. Until the late 1980’s, only one criterion was considered in scheduling problems. Furthermore, until the 1990’s, most work in the area of multiple criteria scheduling consists of bi-criteria studies of the single machine case (Hoogeveen, 1992).

In this paper, an effort has been made to review the publications concerning Multicriteria

Permutation Flow-Shop Scheduling problems, from the late eighties to the most recent papers, giving attention to the results that have not been surveyed until now and suggesting directions for future research (the detailed theorems and proofs have been omitted to avoid a huge paper). In the next section, the classical flow-shop scheduling problem statement is presented. We will briefly introduce MOO theory, general Multicriteria Optimization methods and evaluating metrics (section 3), followed by a survey on multicriteria algorithms devoted to the scheduling problem we are dealing with (section 4). We conclude, in section 5, with a summary discussion on research directions.

## **PERMUTATION FLOW-SHOP SCHEDULING PROBLEM**

In the classical permutation flow-shop scheduling problem, there are  $n$  jobs and  $m$  machines, or stages. Each job needs to complete one operation on each of the machines during a fixed processing time. So, the aim is to find the schedule, or job sequence, that optimizes certain performance measures. In this paper, we focus attention on the permutation flow-shop situation, where all jobs must pass through all machines in the same order. Potts et al. (1991) presents a comparative study of permutation versus non-permutation flow-shop scheduling problems.

The scheduling process involves just finding the optimal job sequencing. Nevertheless, the computational complexity usually grows exponentially with the number of machines,  $m$ , making the problem intractable. This problem, like almost all deterministic scheduling problems, belongs to the wide class of CO problems, many of which are known to be NP-hard (Garey & Johnson, 1979). What it means is that it is unlikely that efficient exact optimization algorithms exist to solve them. Only a few scheduling problems have been shown to be tractable, in the sense that they are solvable

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