Chapter 12
Solving a Bi-Criteria Hybrid Flowshop Scheduling Problem Occurring in Apparel Manufacturing

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ABSTRACT
This paper studies the problem of production scheduling in a company belonging to the apparel industry, where textile labels are manufactured through the process of thermal transfer. The problem is modelled as a flexible flowshop with two stages. The objectives are the maximisation of system productivity (or minimisation of makespan) and the minimisation of the number of production orders with late delivery. This paper proposes a scheduling procedure based on a bi-objective genetic algorithm. An experimental study was performed using real data from the enterprise. Since validation results showed the efficiency and effectiveness of the proposed procedure, a decision-aid tool is designed. The algorithm is implemented at the enterprise and allows improved key performance metrics.

INTRODUCTION
A large number of real-life optimization problems in economics and business are complex and difficult to solve. They cannot be solved in an exact manner within a reasonable amount of time (Talbi, 2009). Using approximate algorithms is the main alternative to solve this class of problems. According to Talbi (2009), approximate algorithms can be classified in two classes: dedicated heuristics and meta-heuristics. The former are problem-dependent and are designed and applicable to a
particular problem. The latter are called meta-heuristics procedures and represent more general approximate algorithms applicable to a large variety of optimization problems. Meta-heuristics solve instances of problems that are believed to be hard in general, by exploring the usually large solution search space of these instances. These algorithms achieve this by reducing the effective size of the space and by exploring that space efficiently. With the improvement of computing performance, the past 20 years have witnessed the development of numerous meta-heuristic algorithms in various communities that sit at the intersection of several fields, including artificial intelligence, computational intelligence, soft computing, mathematical programming, and operational research. Most of the meta-heuristics mimic natural metaphors to solve complex optimization problems (e.g., evolution of species, annealing process, ant colony, particle swarm, immune system, bee colony, and wasp swarm). Meta-heuristics are more and more popular in different research areas and industries.

Scheduling is one of the hard optimization problems found in real industrial contexts for which several meta-heuristic procedures have been successfully applied (Jourdan et al., 2009; Montoya-Torres et al., 2010a). Generally speaking, scheduling is a form of decision-making that plays a crucial role in manufacturing and service industries. It deals with the allocation of resources to tasks over given time periods and its goal is to optimize one or more objectives (Pinedo, 2008; Montoya-Torres, 2010). Among the various types of scheduling problems, flexible or hybrid flowshop scheduling is one of the most challenging. The flexible or hybrid flowshop scheduling problem is known to an NP-hard optimization problem (Gupta, 1988) since it is a combination of the parallel machine and flowshop scheduling problems, which are both known to be hard combinatorial problems, except for strongly restricted special cases. The NP-hardness of the flexible flowshop problem implies that it is not possible to find exact (optimal) solutions to large-sized instances in reasonable computational time. An updated review of solution procedures for the hybrid flowshop scheduling problem can be found in (Ruiz & Vázquez-Rodríguez, 2010).

Among the bio-inspired optimization techniques, perhaps the most known are genetic algorithms (GA) (Guzmán et al., 2010). The objective of this paper is to present a real-life successful application of a genetic algorithm to solve a realistic multi-objective hybrid flowshop scheduling problem. Objective functions are defined as the minimization of the makespan, that is the total duration of the schedule, and the minimization of the total number of tardy jobs (i.e., the number of production orders delivery after a due date).

This paper organized as follows. The paper first describes the problem under study, followed by a review of relevant literature about production scheduling in apparel/textile manufacturing. Then, the detailed description of the proposed genetic algorithm is presented. Afterwards, the computational experiments that validate the use of this meta-heuristic and the results of the implementation in the factory are presented. The paper ends by presenting some concluding remarks.

PROBLEM STATEMENT

Thermal transfer labels industry has experienced an enormous growth in the past decade in Colombia. The Colombian apparel market is demanding every day labels with more variable information, such as size, style, references, descriptions, barcodes, etc. In addition, it is also claiming for a smaller minimum order quantity in production orders that allow the apparel companies request the exact label amount they need. Many times label amount that clients need is not bigger than 500 units per reference, which makes difficult its manufacturing through traditional label production processes: woven label and flexographic printed label processes.