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Multi-Objective Scheduling of Flow-Shop Problems in Finishing Factories Using Genetic Algorithms

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ABSTRACT

The most important trend in chemical finishing is characterized by the key term 'better cost-efficiency relation'. In this work, we have tried to attain inferior cost by optimization of the scheduling of resources using genetic algorithms. This work is divided in two steps. In the first one, we studied the times of production process in order to show the difference between the predicted time and the real time of finishing process. In second one, we have setting up a program for scheduling jobs using multi-objective genetic algorithm.

Keywords: Finishing, scheduling, flow-shop, genetic algorithm

Introduction

Finishing in the narrow sense is the final step in the fabric manufacturing process. Finishing completes the fabric's performance and gives it special functional properties including the final 'touch'. The term finishing is also used in its broad sense: 'Any operation for improving the appearance or usefulness of a fabric after it leaves the loom or the knitting machine can be considered as a finishing step' [1].

The management of the finishing factory is very difficult, particularly because it is necessary to avoid having some machinery in waiting. The goal is the full exploitation of the machinery without overloaded post nor rupture of production while respecting deadline. In fact, the cost of finishing treatment is so elevated, that it represents 25.7% of the costs of materials textile preparation to get finished product (Figure 1). The expenses in energy and the water consumption represent 15 to 21% of the finishing cost [2]. So, two problems must be solved simultaneously: optimization of machinery uses and minimization the energy loss.

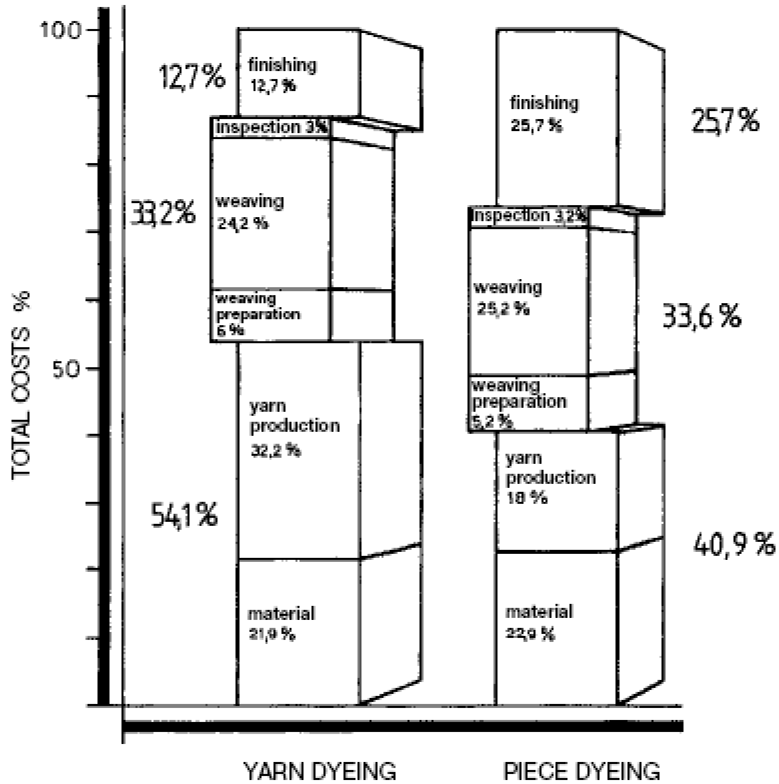


Figure 1: Cost structure of a woven fabric up to finishing [2]

A genetic algorithm is one of meta-heuristic search techniques (Holland 1975) [4] developed, which is based on the mechanism of evolution, and used to solve the scheduling problems. It originates from Darwin's survival of the fittest concept, which means "good parents produce better offspring" [3, 4, 5]. The working of GA was inspired from natural selection in the evolution process. Genetic operator vocabularies are used to develop this meta-heuristic search procedure such as chromosome, population, crossover, mutation, parent, child, etc.

The GA is a stochastic search procedure for combinatorial optimization problems; it's an enumeration technique to find a near optimal solution for problems with a larger number of jobs. The GA is a technique used in order to find an optimum and make sure that the entire solution has been searched with a reasonable degree.

Genetic algorithm

The procedure of genetic algorithm is based on four steps as presented below [3, 4, 6]:

<u>*Step 1: Generation of initial population*</u>

The population of chromosomes is the set of feasible solution. Each chromosome represents the processing sequence of jobs which processed as their order in the chromosome. The range of the processing sequence is randomly chosen to promote large variety of solutions (Figure 2). Each job consists of processing time, initial setup time and completion time (due date).

Chromosome 1 :	Job4	Job3	Job1	Job5	Job2
Chromosome 2 :	Job1	Job4	Job2	Job3	Job5
Chromosome 3 :	Job3	Job5	Job1	Job2	Job4

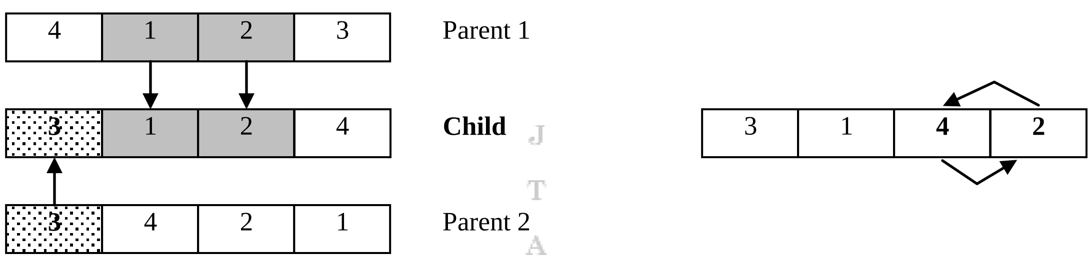
Figure 2: Population of three possible scheduling

Step 2: Calculus of objective function

The evaluation parameter depends on objective function, which depends on the project goal. The goal of the scheduling adjusts according to the project, usually we try to minimize the production time, named makespan. But other methods can be used such as TFT (Total Flow Time), FIFO (First In, First Out], LIFO (Last In, First Out). In the bibliography [3-7], the most studied parameters to evaluate the results are the makespan and the TFT. The population of chromosomes is classified satisfying the small makespan (due date of last job in the last machine).

Step 3: Genetic operators

Two natural phenomena provoking the variation and the improvement of the new offspring are the crossing-over and the mutation (Figure 3). Crossing-over is an operation to generate a new child from two parents by inheriting a job sequence from one of the parent; and the rest of jobs are placed in the order of their appearance in the other parent: it is the core of GA. On the other hand, the mutation is the operation to change the order of the job in the selected chromosome: a job at one position is removed and put in another position. This operation avoids the risk of remaining in the local optimum.



Mutation Crossing-over

Figure 3: Genetic operation

Problem to solve

The objective of this work, known as flow shop scheduling problem with m-machines for n-jobs, is the scheduling of each job of the project; it requires processing in all the machines arranged in line (flow shop). Each job has m operations respecting the order: the first operation on machine 1, the second on machine 2, and so on.

The work is divided in three steps: the first step aims to find exact processing time with consideration of matter preparation and processing constraint. The second step aims to develop and validate a program for scheduling based on genetic algorithm. On the final step, is to optimizing the program to have the best solution.

The first and important objective of scheduling must be the reduction of total job time, known as makespan (C_{max}). But a very important constraint must be considered for machine working at high temperature, like frame stenter in finishing industry, is the minimum arresting time of machine. In fact, for the machine needing high temperature, it's more economical to work without stopping to not dissipate energy.

Experimental design

Genetic algorithm proposed

Many researchers have tried to find out the best performances of genetic algorithm, most of researchers agree that the majority of new population (60 to 80% of population size) must be generated by crossing-over and migrate the rest from the best chromosome [6, 7]. But some studies have shown that in some cases, the existence of bad chromosomes ameliorates the offspring quality.

In our work, we have chosen to generate 70% of new population by crossing-over; the rest was migrated randomly from the initial population. The better mutation probability for best solution is 10%. The population size (number of initial chromosomes) was fixed at 40 chromosomes.

Scheduling objectives

The most important parameter used as the evaluation factor of scheduling quality is the makespan (due date of last job in the last machine). Other parameters can be added to ameliorate the scheduling quality by approaching the real limitation of production like the total flow time (TFT) parameter.

In this study, the assessment of the optimal solution is achieved by two criteria: minimizing the makespan and the nonworking time of machine. In fact, for machines in the finishing factory like the stenter frame or the drying machine, they must be heated before starting the treatment, so it's more profitable to work without stopping the machine for a long time in order to minimize the energy consumption.

Validation of the proposed program

The program was established with visual basic software which allows modifying scheduling parameters easily. Results can be presented as a GANTT diagram or/and in a table containing the numerical results.

To valid proposed GA, we have tested three data illustrated in bibliography [6, 7, 8]. The performance of program was verified by the makespan (C_{max}) then the total flow time (TFT) between other researchers results (article results) and our results.

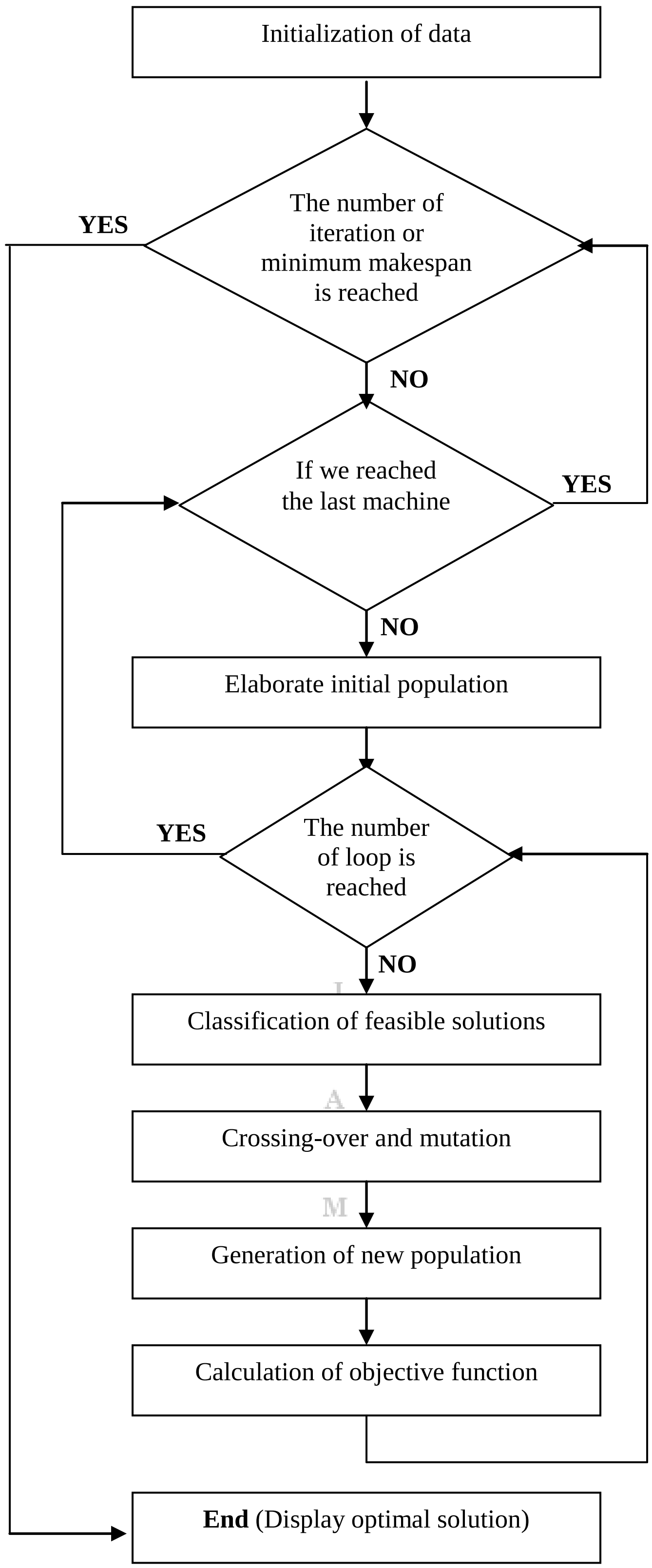


Figure 4: Framework of genetic algorithm

Table 1: Comparison between our program and the illustrated bibliography program

Cited reference	Problem parameters		Article results		Our results		
	Number of machines	*Number of jobs*	C_{max}	*TFT*	C_{max}	*TFT*	*Genetic model parameters*
[6]	2	3	28	73	28	73	$T_{pop} = 20$, $N_{loop} = 20$
[7]	2	5	20	67	20	72	$T_{pop} = 20$, $N_{loop} = 40$
[7]	2	5	20	67	20	67	$T_{pop} = 40$, $N_{loop} = 40$
[8]	5	6	169	*	162	1259	$T_{pop} = 40$, $N_{loop} = 40$

As shown in Table 1, the comparison between our work and some bibliographic program proves the perfection of our program.

Application

Finishing operations

The operations of finishing can be classified into three categories according to processing stage: preparation matter, pretreatment and coloration (dyeing or printing) and finishing.

First, it is necessary to determine the total time of every operation. Determination of this time requires consideration of several important factors: the type of textile being treated (cotton, PET, mixture), the performance requirements, the treatment constraints imposed on the process by the machinery, procedure requirements, and environmental considerations [1].

❖ Matter preparation

The knitted fabrics must be turned-back using turning machine before dyeing to not damage the fabric face. The tubular fabric turning machine is a device for turning tubular knitwear using aerodynamics. The tubular wears is pushed on the turning tube (Figure 5). The end of the piece is drawn into the tube opening, aerodynamically and this turns it at the same time [2].

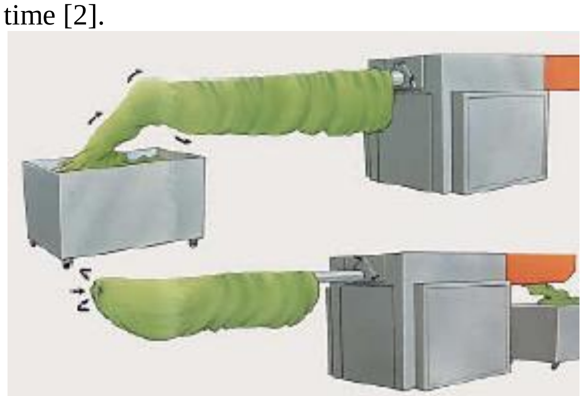


Figure 5: Tubular fabric turning machine from Sperotto Rimar [2]

Since the big capacity of dyeing machine, many knitted fabrics are seamed together to reach the maximum capacity of each dyeing machine.

So the matter preparation time must be considered in scheduling.

❖ Pretreatment and coloration

Pretreatment and dyeing depend on the destination of treated fabric, so it isn't a standard process to follow: relaxing, scouring, bleaching, anti-pilling, dyeing, dyes fixing, washing. It isn't easy to fix the time of each treatment because the vast parameters that influence the dyeing process: fabric quantity, fabric composition, kind of dyes, colors, etc.

❖ After-treatment

After-treatment or finishing treatment are the operations that give stability and final touch of fabrics, the stenter frame is the more known machine to do that for knitted goods. The stenter frame is a unit for thermal treatment of textile fabrics that retain and set the knitted goods width. It consists of an entry zone with an edge guide, one or several drying or setting zones, cooling devices for shock cooling, an exit zone with a batching device and possibly an edge cutting device.

Processing time

It's difficult to fix-up the process time. For example, it isn't easy to control the time of the machine filling with water or the emptying operations, the time of fabric loading, the time of shade tests. In order to solve this problem, a statistic analysis was

carried out to determine the work time of each operation.
Results of statistic analysis showed a good correlation between operation time, kind of dyes, fabric composition and machine. In the next table, the total time of the same finishing operation measured in the factory is showed. This time represents the processing time added to time of knit goods loading, machinery filling, specimen taking, etc.

Table 2: Processing time added according to machine operation

Operation	**Machine**	**Process time**
Matter preparation	*Lockstitch*	1 min/piece
	Turning machine	Average fabric speed 300 m/min (loading and unloading)
Pretreatment and coloration	*SOFT FLOW (450 kg)*	Adding 5% of processing time
	ROTO STREAM (600 kg)	Adding 7% of processing time
	ECOSOFT (1000 kg)	Adding 10% of processing time
Opening tubular fabric	*Cutting machine*	30 m/min
Thermo setting	*Stenter frame*	150 m/min (Depend on the kind of fibers)

Our study permitted to correct the necessary times allocated to finishing treatments. In the former scheduling, only dyeing treatment time has been considered, which generates the disturbance of the planning and the non respect of the delays.

For example, for the job number 1 (Table 3), the indicated processing time was 440 minutes. In reality, this is the anticipated dyeing time without consideration of matter loading, machine filling, laboratory testing, etc. To have finished fabric, the job number 1 needs 675 minutes.

For this case, 9 jobs were chosen to be scheduled using our program; process time of each job was indicated in Table 3.

Table 3: Job Process times

	Prep.	**Dyeing**			**Opening tubular fabric**	**Thermo-setting**	**Characteristics**
		ROTO STREAM	*SOFT FLOW*	*ECOSOFT*			
1	45	470			70	90	Reactive dyes and anti-pilling (CO)
2	15		380		7	10	PET dyes
3	25			720	20	25	Reactive dyes and PES dyes (CO/PET)
4	25			270	20	25	CO Bleaching
5	15		100		7	10	PES bleaching
6	45	300			70	90	Reactive dyes without anti-pilling (CO)
7	45	420			70	90	Reactive dyes without anti-pilling (CO)
8	15		380		7	10	PES dyes
9	25			720	20	25	Reactive dyes and PET dyes (CO/PET)

5.3. Scheduling results

This elaborated program has two objectives, the first one is to minimize the total time of the project (C_{max}). The second one is to minimize the non-working time which take a long proportion of the throughput [2].

For the beginning, only one objective was fixed: minimizing the makespan. The best makespan found is 1780 min (Figure 6) with 40 chromosomes and 20 loops. But it isn't an applied proposition because of the important non-working time of opening machine and frame stenter (three stops of each machine).

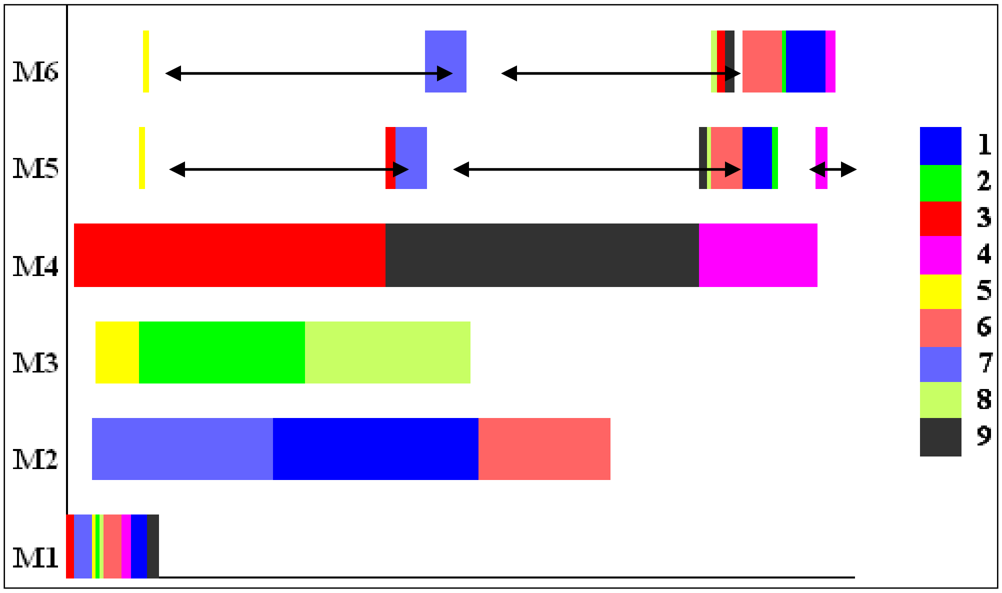


Fig 6: Scheduling proposition with first proposition

To surpass this problem, a second selection criterion was added to evaluate good scheduling.

{For all scheduling -

Select scheduling with the minimum makespan.
If two propositions have same makespans,
then, choose that allows the minimum working time in the machine

Next}

For example, between the two samples in Figure 7, the program select (b) proposition which have minimum non-working machine time.

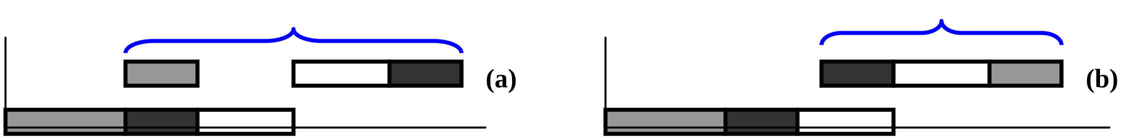


Fig 7: Selection criterion for equal C_{max}

The better scheduling for each machine is which have small difference between the first operation and the last operation in the same machine. This second criterion allows ameliorating the result as shown on the Figure 8. The same C_{max} has been taken, but with one stop in the fifth machine.

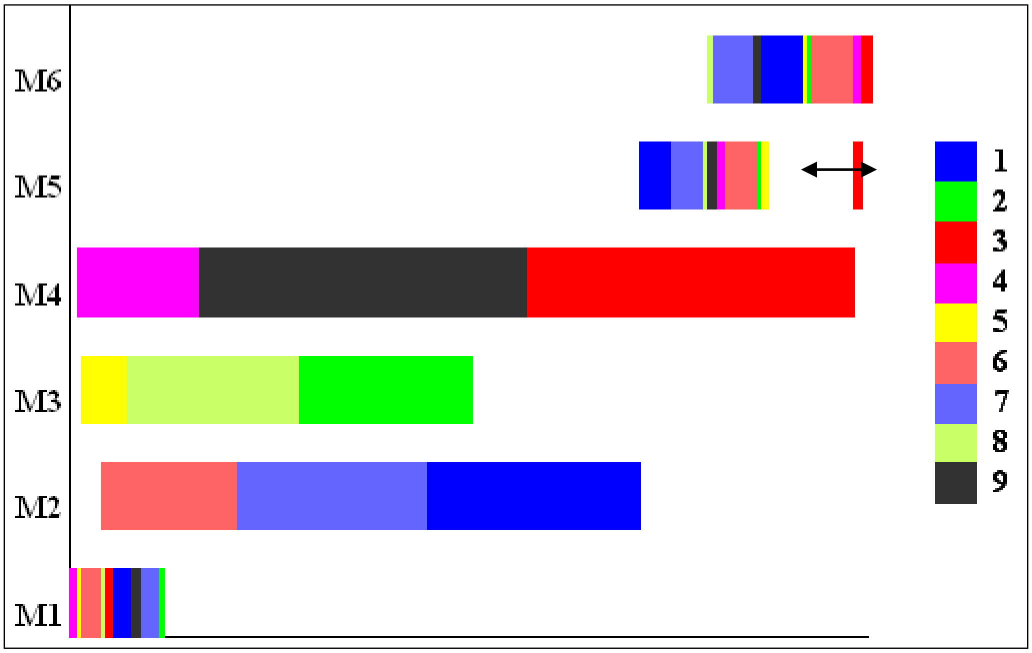


Fig 8: Scheduling proposition with minimum makespan, then minimum non-working time as the objectives

In the third case, a reversal role between the objective functions was applied.

{For all scheduling -

Select scheduling with minimum working time in the machine

If the propositions have same minimum working times in the machine,

Then choose that allows the minimum makespan

Next}

As shown in Figure 9, the scheduling purpose hasn't a stop working machine, but the makespan found is high: 2020 minutes. In result, to have the best project planning, two successive constraints must be verified: minimize the makespan and then minimize the non-working time.

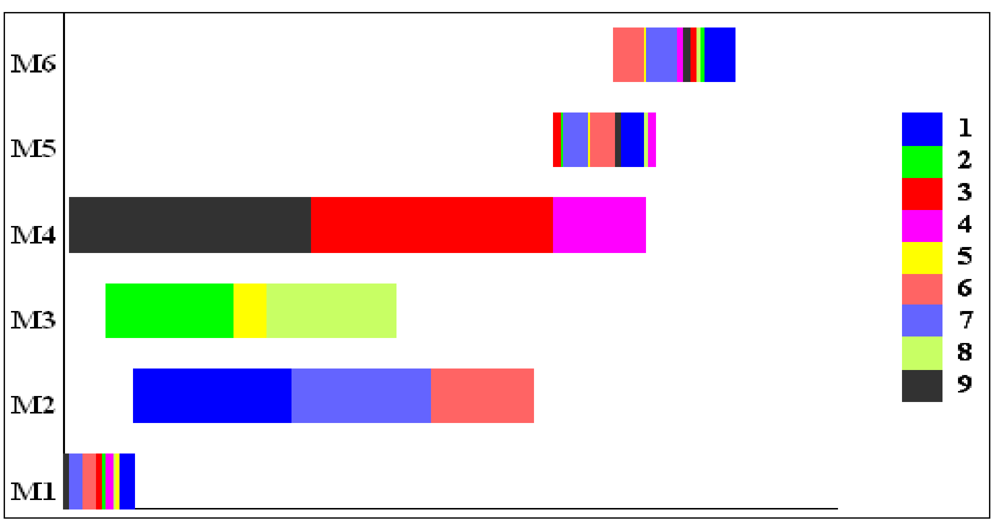


Fig 9: Scheduling proposition with minimum non-working time, then minimum makespan as the objectives

Conclusions

In this paper, several studies were undertaken to ameliorate the planning problem in the finishing factory. A general analysis was carried out to identify the exact time needed for each finishing operation. A corrective coefficient has been elaborated to fit the theoretical dyeing time to the real processing time in the factory.

A new scheduling program based on the multi-objective genetic algorithm has been developed. In first step, we have evaluate the program using literature data to "validate" it. For the finishing industry, makespan is not only the only parameter to consider, but also the non-worked machine time which influences the finishing cost. This program takes in consideration the two constraints. The best results have been found by minimizing scheduling makespan, then minimizing the non-working machine time.

Acknowledgement

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