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Scheduling Optimization in a Cloth Manufacturing Factory Using Genetic Algorithm with Fuzzy Logic for Multi-Objective Decision

Bessem Kordoghli,[1,3] Seifeddine Saadallah,[3] Mohamed Jmali[1,2] and Noureddine Liouene[2]

[1]Textile Research Unit (URT) of ISET Kasr Hellel
B.P 68 Ksar Hellal 5070, TUNISIA, Tel. (+216) 73 475 900, Fax (+216) 73 475 163
bessem.kordoghli@ismmm.rnu.tn

[2]National Enginnering School of Monastir (ENIM)
Av. Ibn EL Jazzar, 5019 Monastir Tunisia, Tel (+216) 73 500 511, Fax (+216) 73 500 514

[3]High Institute of Fashion of Monastir (IS3M)
Av. De GOLF, 5019, Stah Jabeur, Monastir Tunisia, Tel (+216) 73 461 423, Fax (+216) 73 464 212

ABSTRACT

The purpose of this work is the scheduling of trousers collection orders in the department of an important cloth manufacturing society in Tunisia. The scheduling of collection orders differ from the scheduling of production orders. These collections orders are small and average orders of various types of trousers for different international customers. From the anticipated customer information about the collection orders such as the anticipated dates of starting and exporting orders, the quantities of each order and the combined importance of customer and style (fashion or classic style), we have studied the best order scheduling. This solution which takes into account all these information and constraints. In the first step, we have studied the development department method for scheduling orders (classical method) which takes in account only the priority rules either of anticipated beginning dates or by exporting one. In the second step, we have used a second method based on the fuzzy logic to include an importance factor to each order, so that the scheduling problem becomes multi-objective. In order to optimize the result, we have applied the genetic algorithm (GA).

The efficiency of this second method was evaluated by comparing the fuzzy logic scheduling solution to the classical one for the anticipated planning of the manufacturing factory.

Keywords: Scheduling, fuzzy logic, genetic algorithm, cloth manufacturing, development department

INTRODUCTION

In a modern cloth manufacturing factory, the customer order must follow three steps:

- Development of the wear: doing the pattern and making up the specimen. This step allows the evaluation of the factory capacity to produce a garment with making request quality.

- Collection: after the first specimen validation, the factory must produce a few number of this wear to check the customer point of view. Actually, this small quantity (collection quantity) is useful to study the customer behavior.

- Production: make up the order when the collections are accepted by the final consumer.

A perfect scheduling must be applied to have a good management of factory resources. The evaluation parameters of scheduling depend on objective function, which depends on the project target. The goal of the scheduling must be adjusted according to the project; we usually try to minimize the production time, known as makespan (due date of last job in the last machine) [3, 4].

For the development department, the makespan is not the most important objective; however in this section the execution of maximum of orders in the time and the satisfaction of prospective customer are the two main objectives. To reach those objectives, we have to search for priorities between customer orders with respect to export date, the average production capacity, and the customer importance associated to the style difficulties (fashion or classic style). This problem is known as multi-criteria scheduling problem.

The multi-criteria scheduling problem is one of the main research subjects in the field of multiple objective programming. Several procedures have been developed to deal with this type of problem where some conflicting criteria have to be simultaneously optimized [1].

Scheduling problems frequently arise in industrial processes, good manufacturing systems, production echelon lines, total quality, efficacy management, etc. Many different approaches have been applied to solve the scheduling problems and have obtained effective result. Genetic algorithms, were originally developed by Holland in the early 1970s, were applied to a large number of complex search problems [2]. For the simultaneous multi-criteria selection, the fuzzy logic technique must be a good solution.

In the next paragraphs, the studied problem will be explained, the principles of the two scheduling techniques adopted in this work (genetic algorithm and fuzzy logic) will be detailed, and finally their results will be discussed.

MAIN HEADINGS

Problem to solve

Firstly, the in-charge client relation asks the customers their anticipated orders before the beginning of the season; these previsions must include the collection quantities to produce, the forecast dates of starting the order (starting week), and for ending the order (export week). Table 1 displays the anticipated customer orders for four weeks (from week 45 to 48).

Table 1: Anticipated customer orders (collections)

Order	Quantity	Starting week	Export week	Importance
A	773	45	49	0.5
B	460	45	49	0.25
C	743	45	50	0.75
D	1232	45	50	1
E	880	45	51	1
F	370	46	50	0.5
G	750	46	50	0.25
H	570	46	50	0.25
I	1790	46	50	0.5
J	1068	46	51	0.75
K	649	46	52	0.1
L	300	47	51	0.25
M	750	47	51	0.75
N	680	48	52	1

On one hand, we have given to each order an importance factor which depends on customer importance and on style difficulties (fashion or classic styles present in the order). These factors vary from 0.25 to 1.

On the other hand, the cloth manufacturing factory of the development department has an average production capacity of 1200 trousers per week (fashion and classic style together).

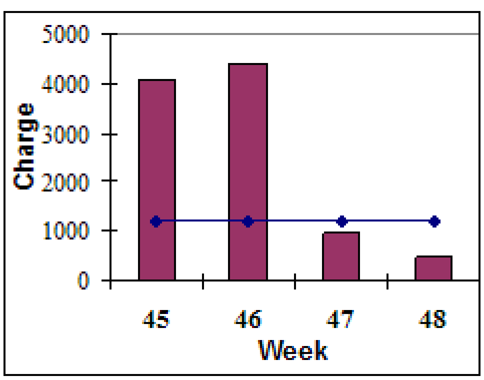


Figure1: Anticipated weekly charges

Figure 1 shows the comparison between the weekly anticipated charges and the capacity. As one can see the comparison shows that for weeks 45 and 46, the charge is too high compared to production capacity, whereas the opposite is found for weeks 47 and 48. In this paper we propose to solve these unbalanced charges.

Scheduling by priority rules

The scheduling in our case has the purpose to balance the production charges between the weeks with respect to order priorities in terms of the anticipated date of order beginning and/or export dates. The average production capacity of the manufacturing factory of the development department will be used to determine the delays (date out). In this step, we will not take in account the order importance factor.

After applying this method of balancing the charges between weeks, new planning is found either by sorting out orders by the anticipated starting date as shown in table 2 or by the exporting date as shown in table 3.

The job margin is defined by the following equation:

$$margin = \frac{Export\ date - Date\ out}{Export\ date - starting\ date}$$

If the margin is negative, then the job will be considered as too late.

Table 2: Planning after sorting out by the order starting date

Orders	Date in	Date out	Margin	Importance factor
A	45	45	1	0.5
B	45	45	1	0.25
C	46	46	0.8	0.75
D	46	46	0.8	1
E	47	47	0.667	1
F	47	47	0.75	0.5
G	47	48	0.5	0.25
H	48	48	0.5	0.25
I	48	50	0	0.5
J	50	51	0	0.75
K	51	51	0.167	0.1
L	51	51	0	0.25
M	51	52	-0.25	0.75
N	52	53	-0.25	1

Table 3: Planning after sorting out by order exporting date

Orders	Date in	Date out	Margin	Importance factor
A	45	45	1	0.5
B	45	45	1	0.25
C	46	46	0.8	0.75
D	46	47	0.6	1
F	47	47	0.75	0.5
G	47	47	0.75	0.25
H	47	47	0.75	0.25
I	47	49	0.25	0.5
E	49	50	0.167	1
J	50	51	0	0.75
L	51	51	0	0.25
M	51	52	**-0.25**	**0.75**
K	52	52	0	0.1
N	53	53	**-0.25**	**1**

We can conclude that either for sorting orders by the anticipated starting date (table 2), or by sorting out orders by export dates, the orders M and N are too late because the jobs margins are negative. Those scheduling solutions are not so good because the orders M and N are important orders with too high importance factors (0.75 for M and 1 for N). Therefore, the classical order scheduling by priority rules are not the best method.

The purpose of the fuzzy logic is to find a better solution which can take into account the importance factor with respect to priority rules. In fact, fuzzy logic must give a scheduling solution where negative job margins are not found for important orders.

Advanced techniques of resolution

Genetic algorithm

A genetic algorithm is one of meta-heuristic search techniques developed (Holland 1975) [6], 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" [5, 6, 7]. The working of genetic algorithm 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 genetic algorithm is a stochastic search procedure for combinatorial optimization problems; it's an enumeration technique to find a near optimal solution for the problems with a larger number of jobs. The genetic algorithm is a technique used in order to find an optimum and make sure that the entire solution has been searched with a reasonable degree.

The procedure of genetic algorithm is based on three steps as presented below [5, 6, 10]:

Step 1: Generation of initial population

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

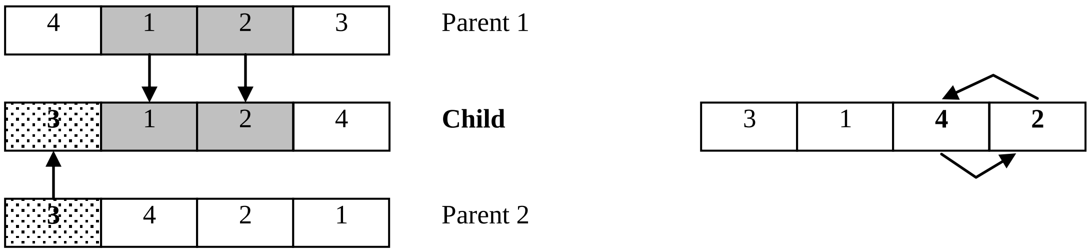
*Step 2: Calcula*tion *of objective function*

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 [5-7, 10, 11], 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).

For this paper, two criteria must be considered in the same time; that's why we must use the fuzzy logic.

Step 3: Genetic operators

The two natural phenomena provoking the variation and the improvement of the new offspring are the crossing-over and the mutation (figure 3). The 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 is 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

Fuzzy logic

The fuzzy logic is based on the fact that an object can belong to a group and at the same time to his complement [8, 9]. Therefore, different objectives can be evaluated at the same time.

In the fuzzy logic case, we varied the coefficients of decisions (D_{ij}). These coefficients are the result of the association of two criteria: the job importance subsets and the jobs margins subsets which are detailed below.

Table 4: Fuzzy system design

		Job Importance		
		Middle	Good	Very good
Jobs margins	Too late	D_{11}	D_{12}	D_{13}
	In time	D_{21}	D_{22}	D_{23}
	Too early	D_{31}	D_{32}	D_{33}

Job importance subsets

In our project, we give to every job (order) a coefficient of importance depending on customer/style classification (middle, good or very good); these coefficients indicate the priority of the job. More this coefficient is raised, more the order must be produced before the delivery date. In fact, this coefficient can present the priority of a job because the customer is important for the society.

Jobs margins subsets

In the ideal orders scheduling case:

- It is necessary to avoid having a delay of production: every delay will be followed by a penalty.
- It is necessary to avoid producing the job very early because of the storage expensive cost and to give priority to urgent jobs.

For those reasons, jobs margins are subdivided into 3 subsets: Too Late, Too early and In Time. The latter will be considered as the best solution.

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 [10, 11]. 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.

Fuzzy System design

In our work, we considered that:

- The fuzzy groups have the importance factor and the job Margin.

- The fuzzy subsets are middle, good and very good for the importance; and too late, in time and too early for the delay. The purpose is to define the inference of the rules.
- The *Dij* decisions were varied until we have obtained the best solution in terms of jobs margins and of customer/style importance (Table 5).

Table 5: The best Fuzzy system design

		Job Importance		
		Middle	Good	Very good
Jobs margins	Too late	1	0.5	0.1
	In time	3	5	8
	Too early	1	3	5

We only considered a two input system: The Importance of the job and the jobs margins. Only one output (response) that must take place: V (I, J).

Every entry will be divided into three fuzzy subsets according to figures 4 and 5.

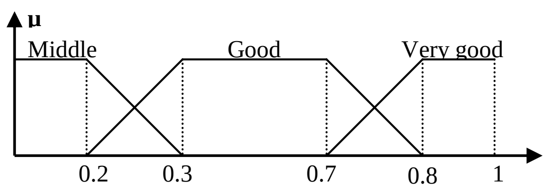


Figure 4: Importance subsets

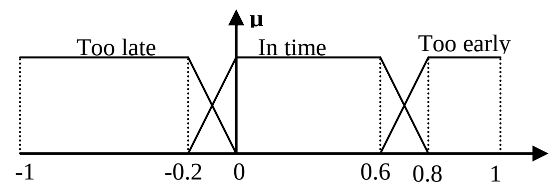


Figure 5: Scheduling margin subsets

To determine the fuzzy factor (response), we used the Sugeno rules [12] that allow more flexibility in the programming.

The program

First, the genetic algorithm is used for random choice of a number N of possible solutions. The genetic algorithm is then used to create a second group of possible solutions (by crossing over and mutation). But the selection of the best solution is done by the fuzzy logic method which gives a solution respecting two criteria at the same time. This resolution process is summarized in figure 6.

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

Table 6: 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.

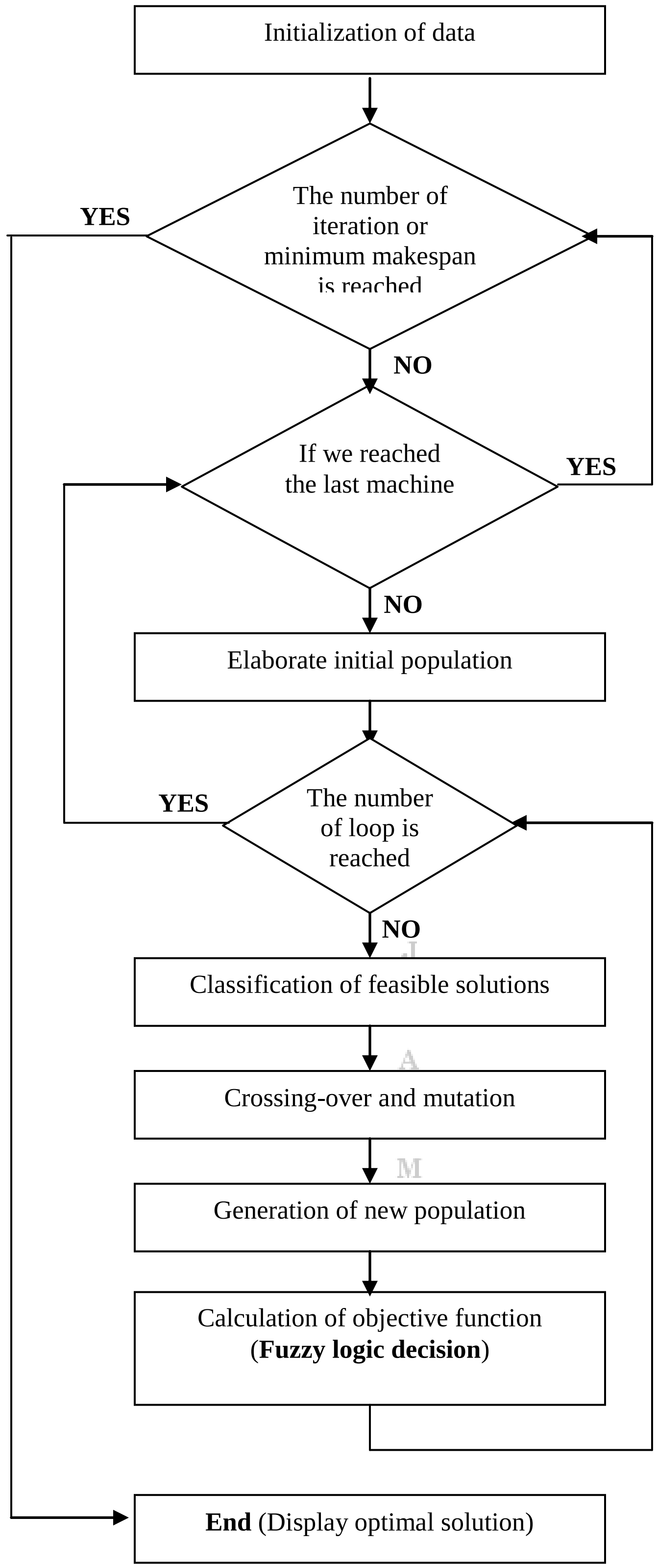


Figure 6: Framework of genetic algorithm

Application of fuzzy logic on our project

The fuzzy system design detailed above is applied to resolve our orders scheduling problem.

After each scheduling operated by the genetic algorithm, we calculate the fuzzy factor which takes into account either the order importance and the manufacturing delay in respect of the model proposed in table 5 and figures 4 and 5. First, we have done the scheduling taking into account just the priority rules FIFO (First In, First Out) and FOFI (First Out, First In); the results are shown in table 7 and 8 respectively.

After the previous step, we have calculated the fuzzy factors for three cases: classical scheduling (priority rules by orders beginning dates or by orders exporting dates) as mentioned in table 7 and 8, and an optimized fuzzy logic scheduling solution found by successive iterations (table 9).

Table 7: Fuzzy calculations for the planning after sorting out by the order starting date

Orders	Date in	Date out	Importance factor	Margin	Fuzzy factor
A	45	45	0.5	1	0.1127
B	45	45	0.25	1	0.0751
C	46	46	0.75	0.8	0.1503
D	46	46	1	0.8	0.1503
E	47	47	1	0.667	0.2669
F	47	47	0.5	0.75	0.1503
G	47	48	0.25	0.5	0.1503
H	48	48	0.25	0.5	0.1503
I	48	51	0.5	0	0.0187
J	51	51	0.75	0	0.2443
K	51	51	0.1	0.167	0.0375
L	51	52	0.25	0	0.1503
M	52	52	0.75	-0.25	0.0112
N	53	53	1	-0.25	0.0037
				Total	**1.7894**

Table 8: Fuzzy calculations for the planning after sorting out by order exporting date

Orders	Date in	Date out	Importance factor	Margin	Fuzzy factor
A	45	45	0.5	1	0.1127
B	45	45	0.25	1	0.0751
C	46	46	0.75	0.8	0.1503
D	46	47	1	0.6	0.2669
F	47	47	0.5	0.75	0.1503
G	47	47	0.25	0.75	0.0939
H	47	47	0.25	0.75	0.0939
I	47	49	0.5	0.25	0.1879
E	49	50	1	0.167	0.3007
J	50	51	0.75	0	0.2443
L	51	51	0.25	0	0.1503
M	51	52	0.75	-0.25	0.0112
K	52	52	0.1	0	0.1127
N	53	53	1	-0.25	0.0037
				Total	**1.8383**

Tables 7 and 8 show that the two important orders M and N (with high importance factors) are too late (negative margin); furthermore, for the FIFO method (sorting out by the order starting date), we obtain a total positive margin for all the orders of +6.2 (advance in production: stock) and a total negative margin of 0.5

(delay in production). For the FOFI method (sorting out by order exporting date), we obtain a total positive margin of +6 and a total negative margin of 0.5.

However, if we operate selection by the fuzzy logic method (calculated fuzzy factor), we will have only the less important H and K orders too late (table 9), but we will have better total positive margin of +5.4 (less advance in production, so less stock) and better total negative margin of 0.66.

Figure 7 summarizes the differences between the three types of scheduling in terms of total positive margin (advance in production), total negative margin (delay in production) and total fuzzy factor.

Table 9: Fuzzy logic optimized planning

Orders	Date in	Date out	Importance factor	Margin	Fuzzy factor
A	45	45	0.5	1	0.1128
B	45	45	0.25	1	0.0752
C	46	46	0.75	0.8	0.1504
D	46	46	1	0.8	0.1504
E	47	47	1	0.667	0.2669
F	47	47	0.5	0.75	0.1504
I	47	49	0.5	0.25	0.188
J	50	50	0.75	0.2	0.2444
G	50	50	0.25	0	0.1504
M	50	51	0.75	0	0.2444
L	51	51	0.25	0	0.1504
N	51	52	1	0	0.3008
H	52	52	0.25	-0.5	0.0282
K	53	53	0.1	-0.16	0.0226
				Total	**2.235**

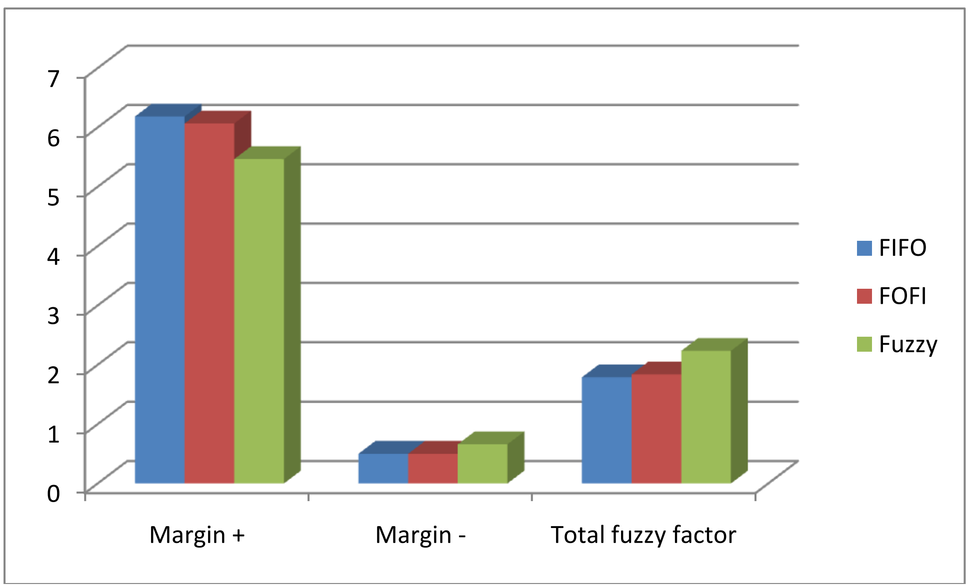


Figure 7 : Effect of the method of selection on the scheduling results

Table 9 shows that only the two collection orders H and K, which have a minimum importance factor are too late. This scheduling solution seems to be better than the two previous classical scheduling solutions. We can also note that the total fuzzy factor of the optimized orders scheduling solution (2.235) is higher than those of the classical scheduling solution (1.789 and 1.838).

CONCLUSIONS

This study shows that the planning of collection orders cannot be done by classical priority rules only, because of the existence of another qualitative parameter like the order importance (combination of customer/style importance to the manufacture). A new scheduling program based on the genetic algorithm has been developed with visual basic software. In a first step, we have evaluated the program using literature data to show its effectiveness. After that, a comparison between the genetic algorithm scheduling results and the classical priority rules results have shown that the genetic algorithm with the fuzzy logic optimizes the scheduling solution. In fact, the two orders which are too late have very low importance in the fuzzy logic solution, comparing to two important orders out of date (too late) for the classical priority rules solutions. Otherwise, the total fuzzy factor is higher for the better scheduling solution in accordance to the optimized total margins showing that this factor is a good indicator of the multi-criteria scheduling (the two criteria of priority rules and orders importance).

It is now obvious that the fuzzy logic can be a good method for multi-objective orders scheduling taking into account priority rules and the orders importance factors.

The clothing industry and especially the development departments will find in this work a good approach to resolve their multi-criteria scheduling problems.

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