MODELING AND SIMULATING A TEXTILE PRODUCTION SYSTEM

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ABSTRACT

This paper presents a study for a production scheduling problem in a textile company, specifically in the weaving preparation area. Basically, the processing orders can be considered as sequential working steps trough three operations (charging - weaving - discharging), and the goal is to minimize time variation and to avoid delays. The machine utilization should be as higher as possible due to short delivering deadlines. The production unit has got 4 of these weaving machines functioning at the same time.
Four dispatching rules were tested in order to find the best solution. The optimization procedure highlighted some interesting issues that are discussed in this paper.

INTRODUCTION

This work focused mainly on the production programming problem in the weaving preparation area of a textile company. The production function became a main concern faced by managers once new problems arise due to the huge number of products and the uncertainty on demand. These two factors reduce the company productivity and competitiveness
Nowadays, a large number of companies are changing their production systems to this new reality. There are several tools in the market to support the decision to plan and control the production. Programming the production is an important concern to the companies because they want to maximize the utilization of their resources, increasing productivity without compromising flexibility. However, this is a well known hard problem with a high level of complexity, where a mathematical solution could not be obtained in a short time period.
In this paper we present a study to solve this production scheduling problem. We present a decision support system based on heuristic rules and a simulation model.
The main objective of the production schedule is to define the sequence of the jobs that involve three operations (loading – weaving – unloading) in order to minimize time variation and to avoid delays. The machine utilization should be as higher as possible due to short delivering deadlines. The production unit has got 4 of these weaving machines, functioning as parallel machines.
A literature review has been performed in order to identify related heuristics to schedule the orders. The selected and applied heuristics were: SPT (Shortest Processing Time), NOB (Number Of Bobbins), EDD (Earliest Due Date) and FAP (Family Articles Processing). Based on those dispatching rules, manufacturing orders were sorted and performance evaluated accordingly.
Results were evaluated in a simulation model using Arena software, in order to make the acceptance or rejection of heuristics considering the numerical results and the model animation helped model validation by the company decision makers.

THE PROBLEM

The main problem is related with a process composed by three operations: load an order, make a fabric, unload the order. The shop floor has four parallel (identical) machines. In each machine there are two devices to load an order. Loading an order means to put about 740 bobbins with the cotton thread in the machine. Figure 1 shows a view of the warehouse, where it is possible to see several pallets with bobbins of cotton thread.

Figure 1: Bobbins of cotton thread

Figure 2 shows the textile machine to produce the fabric. The machine has two device loaders - this allows to use one of them with one order, while it is possible to unload the previous order and also to prepare (to load) the next order.

Figure 2: Textile machine

Figure 3 shows a representation for the machine and the two device loaders which will be used in the simulation package to animate the simulation.

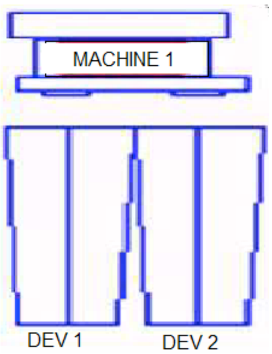

Figure 3: Machine and devices loaders

Figure 4 represents the machine device loader with several bobbins with several colors to produce one pattern.

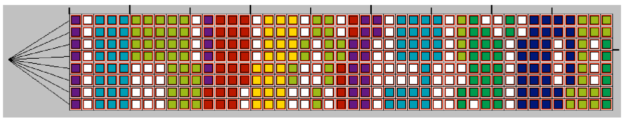

Figure 4: Device loader with different colours

Figure 5 presents the layout of the shop floor where four machines are available, the respective devices loaders, a warehouse of raw material, and two workers per machine. In each machine there are a skilled hand to operate the machine and a auxiliary worker which load and unload the machine with the orders. Figure 5 is used in the simulation package to animate the simulation.

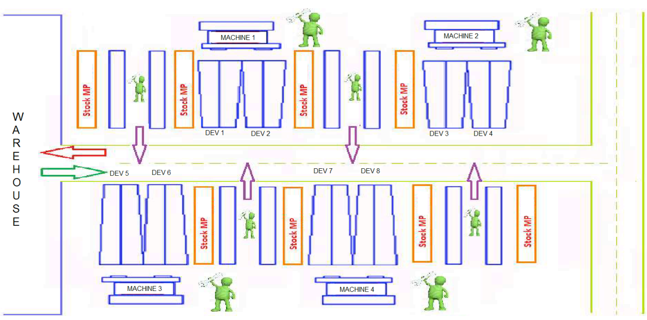

Figure 5: The layout

There are six different states to be considered in this process for the machine and its two devices. The machine itself could be 1) **waiting** for the next order; 2) involved in a **setup** procedure; 3) **operating** to produce the fabric. On the other hand, the device loaders could be 4) **loading** the set of bobbins for the next order; 5) **busy** with loaded order; 6) **unloading** a finished order. Figure 6 shows a Gantt Chart to present the several states of the machine and the devices.

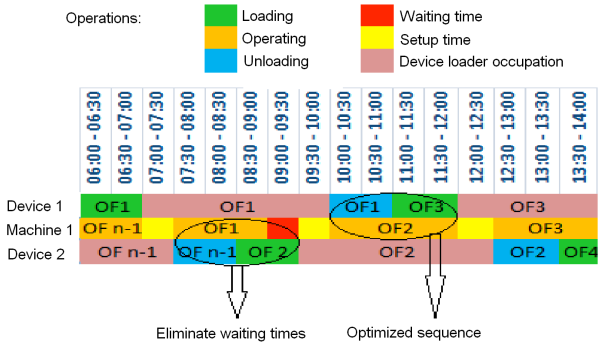

Figure 6: Gantt chart

In this small example we present the sequence of four orders (OF i) and also the previous one (OF n-1). It is possible to verify that when OF 1 is finished the machine must be idle until loading of OF 2 on Device 2 is completed. In the meantime, to produce OF 3 the machine does not need to wait for the conclusion of loading order in the Device 1. The operating time of each order is variable and depends on the quantity (in meters) of fabric to be produced. Also, the time to unload an order and to load the next order in a device depends on the number of bobbins to be changed in the device. If a consecutive pair of orders prepared in the same device share the same color (bobbin) it is not necessary to remove that bobbin from the device to replace it again in the device. This property allows to save time on both unloading and loading operations in the device.

This real problem could be considered as a generalization of the well known problem of scheduling operations in a flexible manufacturing system where it is necessary to change the tools of a machine. The particular situation of one machine could be modeled as a traveling salesman problem, where the sequence of orders could minimize the time to change the tools on the machine.

MODELING THE REAL PROBLEM

This real problem could be modeled as a deterministic combinatorial optimization problem, in particularly as a variant of the multiple traveling salesman problem (mTSP), which consists of determining a set of routes for *m* salesmen who all start from and turn back to a home city.

The mTSP can be considered as a relaxation of the vehicle routing problem (VRP), with the capacity restrictions removed (Bektas 2006). This means that all the formulations and solution approaches proposed for the VRP are also valid and applicable to the mTSP, by assigning sufficiently large capacities to the salesmen (vehicles). The mTSP is a NP-complete problem (Husban 1989). To find an optimal solution to the mTSP using exhaustive search is only possible for a very small number of nodes. An alternative to find solutions for this kind of problems is using heuristics, such as evolutionary algorithms (Fogel 1990), simulated

annealing (Song et al. 2003), tabu search (Ryan et al. 1998), ant systems (Pan and Wang 2006), etc.
The company is facing new difficulties related with the huge number of different (type of) products that are produced and the uncertainty on the demand. This known variability made the authors decide to study the real problem using a simulation model. Indeed, the system under investigation is complex and it is not possible to find analytical solutions. Nevertheless a deterministic model is not enough to represent the real problem, due to demand fluctuations, and design changes must be considered. Taking into account the complex stochastic characteristics of the system, simulation is the most suitable tool to predict system behavior and is a powerful operations research technique to use. In particular, discrete event simulation has proved to be a useful tool for evaluating the performance of such systems.
The current manufacturing system is analyzed by a simulation model emphasizing the bottlenecks and the poorly utilization of the machines. The main idea is to develop a simulation optimization based decision support system where simulation outputs would validate analytical results, incorporating variability in the process and allowing important sensitivity analysis of the solutions found.
However, a simple evaluation of performance is often insufficient and a more exploratory process may be needed in the form of simulation optimization. As stated by Ólafsson and Kim (2002) simulation optimization is the process of finding the best values of some decision variables for a system where the performance is evaluated based on the output of a simulation model of this system. However, the major drawback of simulation for practical applications is that it is computationally time consuming. There has been a great deal of work on simulation optimization in the research literature, and more recently optimization routines has been incorporated into several commercial simulation packages. Fu (2002) presents an exhaustive tutorial that summarizes the existent approaches and provides a discussion contrasting these approaches with the algorithms implemented in commercial software.

SIMULATION TOOL SELECTION

According to Dias et al. (2011) most of scientific works related to tools comparison/reviews only analyze a small set of tools and usually evaluating several parameters separately avoiding to make a final judgment due to the subjective nature of such task.
An extensive review about simulation software could be found in Dias et al. (2011):

> "In the Industrial Engineering Magazine (1993/July) there is a list of 45 commercial simulation software products. The sixth biannual edition of simulation software compiled by James J. Swain in 2003 identifies about 60 commercial simulation products, 55 in 2005 and 48 in 2009 (Swain, 1991-2009). The annual 2004 SCS edition – (M&S Resource Directory) lists 60 simulation products. In the (Simulation Education Homepage - Simulation tools list by William Yurcik) there were more than 200 simulation products, incl. non commercial tools."

The study produced by Dias et al. (2011) started with Swain´s list, removing non discrete event simulation environments, and adding some tools found in more than one list sources. Dias et al. (2011) support that the three most popular simulation packages are Arena, Simul8 and Witness. Figure 7 presents the ranking presented by Dias et al. (2011). The authors believe that the Top 10 "popular" simulation commercial tools are included in that list (of 19). As well as it is most probable that this list includes the top 10 "most used" and "best" contemporary simulation tools.

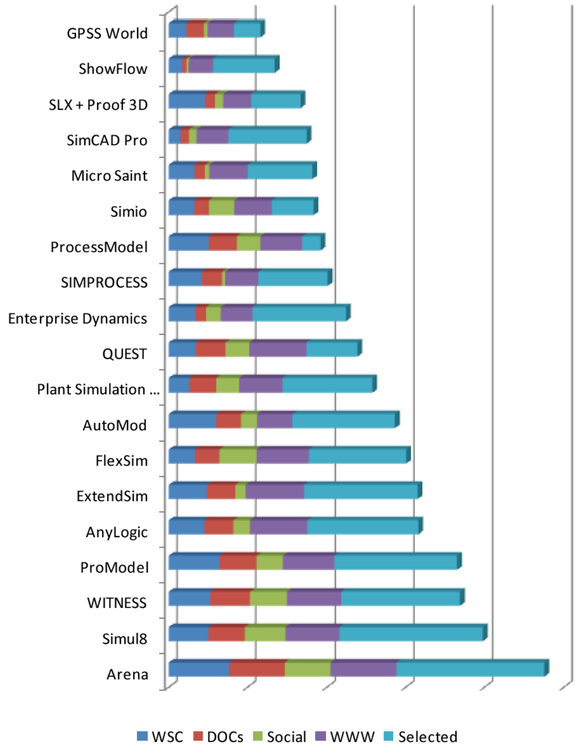

Figure 7: Popularity ranking (Dias el al. 2011)

The chart in Figure 7 can help to visualize the strengths and weaknesses of each tool, in a comparative analysis.

THE MODEL

Figure 7, showing an interesting simulation software popularity ranking moved us to choose Arena Software from Rockwell Automation, Inc to construct a model to this real problem. Arena is built over the SIMAN simulation language. Arena is based in the process simplification through discrete events. After creating a simulation model graphically using base Arena templates and the primitive building blocks and establishing links between blocks (to represent the process logic), Arena automatically generates the underlying SIMAN model used to perform simulation runs. In Arena package it is not necessary to develop code, since the modeling process is graphical. The Arena modeling system is a flexible and powerful tool that allows analysts to create animated simulation models that accurately represent virtually any system. The Arena Professional Edition also includes the functionality of OptQuest, for optimizing systems.
To implement this model, it was necessary to collect real data from the company, particularly to define operations processing times. To aid this task, it was collected from the real process registries using MS Access equivalent to one month and later the data was compiled in a spreadsheet.
Using ARENA INPUT ANALYZER functionality the elementary processing times were fitted to statistical distributions, based

on historical data. Figure 8 shows expressions of modeled tasks, detailing one of them (*Charging*) as output of Arena.

Task	Expression	% Error
Search yarn	1.5 + LOGN (3.16, 2.24)	5,50%
Charging	TRIA(6.5,11,20.5)	1,20%
Splice	6,5 + 13 * BETA (1.06, 1.3)	0,57%
Mince Comb	0.5 + WEIB (1.63,1.75)	0,029%
Weaving	1.5 + GAMM (0.582,4.14)	0,40%
Pass	8.5 + 12 * BETA (2.99,1.92)	0,70%
Discharging	1,5 + 9 * BETA (1.88,2.09)	0,64%

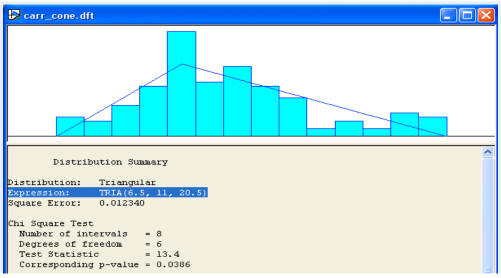

Figure 8: Arena Input Analyzer usage

It was developed the communication between Arena and the enterprise resource planning (ERP) system to load the existent orders.
To import data from the spreadsheet (MS Excel) to the Arena, we developed a Visual Basic Application routine, presented at Table 1.

Table 1: Visual Basic Application routine

```
Private Sub ModelLogic_RunBeginSimulation()
    Dim m As Model
    Set m = ThisDocument.Model
    Dim FileToOpen As String
    Dim ArenaDir As String
    Set XL = GetObject("", "Excel.Application")
    ArenaDir = Mid(m.FullName, 1, Len(m.FullName) - Len(m.Name))
    FileToOpen = ArenaDir & "testearena.xlsx"
        XL.Workbooks.Open FileToOpen
End Sub
```

In Figure 9 there is a “cloud” of the Arena Model (network of building blocks), with the loading area (from ERP system), the splitting area (to the four machines) based on the selected heuristic, and control logic for each machine.

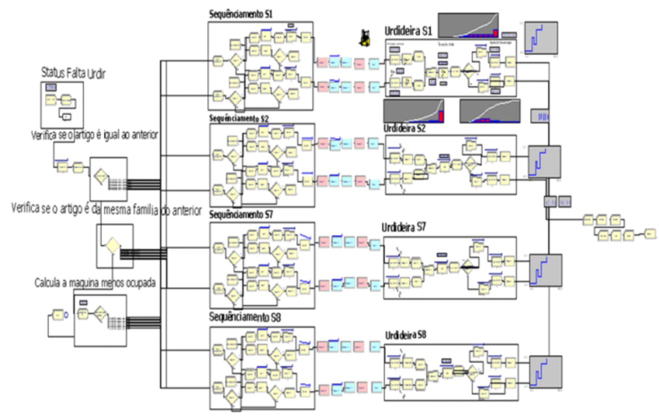

Figure 9: Arena Model

The simulation model developed in Arena makes use of the tool animation feature to better discuss and validate results with decision makers. Figure 10 shows one screenshot of the animation area , constructed accordingly to the real layout as shown if Figure 5.

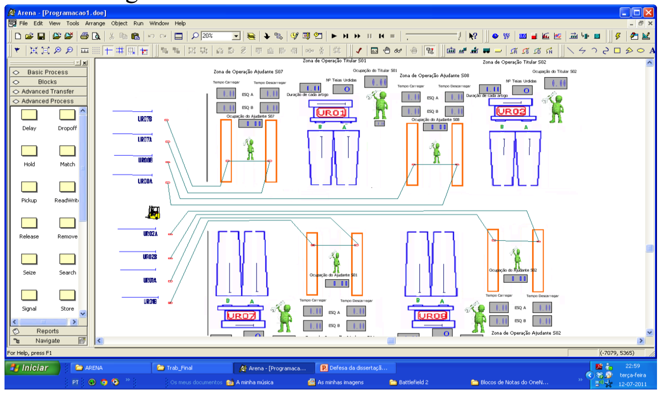

Figure 10: Arena Model Animation Screenshot

THE EXPERIMENTAL RESULTS

To study the several important factors of performance four orders dispatching rules were selected: SPT (Shortest Processing Time), NOB (Number Of Bobbins), EDD (Earliest Due Date) and FAP (Family Articles Processing). The main outputs considered to evaluate the performance of the system are machine utilization, linear metre per hour of fabric, woven fabric per hour, man power utilization and production time.
Table 2 presents production outputs retrieved from computational experiments preformed with simulation software which allow us to compare the selected dispatching rules.

Table 2: Productions outputs

	Real Prod	Real P Sim	FAP	SPT	EDD	NOB
Productivity (metre/hour)	150	150	210	192	189	186
Productivity (woven fabric/hour)	0.24	0.24	0.34	0.31	0.3	0.3
Machine Occupation	52%	46.5%	63.3%	59.75%	58.75%	58.25%
Manpower Occupation	-	-	75%	93.25%	92.5%	91.25%
Production time (hours)	7380	7380	5276	5768	5864	5948

The results presented at Table 2 shows a 5.5% less utilization of the machine in the simulated real production. Besides this short difference validates the model, it could be related with small operations that exit in the real process and they are not included.
The FAP dispatch rule presents a machine utilization rate of about 63%. This simulation result foresee an increase around 11% comparing with the achieved value in the real situation, and 16% better than the simulated real production. With this option the productivity increase 60 metres per hour. The man power utilization is also increased significantly comparing with others dispatching rules. Although there is an important disadvantage of this rule – it does not take into account the due dates of the orders, and can therefore generate delays to deliver the orders.

The SPT rule achieved an improvement of 7% in terms of utilization rate and increases productivity in 42 meters per hour.

EDD and NOB have similar results and increase productivity in 36 meters per hour.

Globally the FAP rule seems to be the bestoption to be implemented but still needs a plan that consider similar products to be jointly sequenced

CONCLUSIONS AND FURTHER WORK

This textile company must be able to adapt to its customers' ever-changing needs and improve the quality of its products in order to survive. It is important that the company responds quickly to rapid changes in demand fluctuations, and design changes. These needs have forced to put emphasis on automated systems to improve productivity.

Many systems in areas such as manufacturing, supply chain management, financial management, are too complex to be modelled analytically. Discrete event simulation has long been a useful tool for evaluating the performance of such systems.

The goal of this paper was to provide a formal model to one important problem in production management, specifically the one related to constrained resources utilization and its implementation.

The more suitable orders dispatching rule is Family Articles Processing since benefits on lower times to load and unload orders increased the productivity about 11% allowing the production of more 60 meters of fabric per hour.

Finally, it can be stated that the state of the art of simulation adopted in this paper as a DSS for modelling real production system can prompt management to compare the existing system and the proposed new process, and to find near-optimum values of the decision variables. It is shown that the proposed DSS is used effectively to improve the production rate, and results show a substantial decrease on the overall production time.

This research also demonstrates how simulation modeling can be used to design and optimize real production systems. Shortly, we intend to explore the optimization package OptQuest and to compare with more dispatching rules to sequence the costumers orders.

In a further research we intend to explore more heuristics from combinatorial (discrete) optimization to be employed in the simulation models.

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BIOGRAPHY

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