COMPARATIVE ANALYSIS BETWEEN SCHEDULING TOOLS FOR CUTTING SHEET METAL INDUSTRY

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Abstract: In order to be competitive, companies need to embrace sustainable policies and practices. Company leaders are taking a new stand on sustainability, recognizing that there is opportunity inherent in the need to provide solutions to the world's environmental and social challenges. This paper addresses a very common objective in Industry: how to radically improve efficiency for core processes and activities, in order to reduce waste and resources consumption, through the use of operational planning tools.

The present paper summarizes the research work conducted in a metal cutting sheet manufacturing company. The study involved the analysis of the company production process and the investigation of the working methods in order to evaluate material consumptions, response time and overall plans efficiency.

Keywords: Production Planning and Programming, Scheduling, Scheduling Tools Technology.

I - INTRODUCTION

As a result of markets globalization and the growing competition, a constant innovation in products, production processes and services is needed. The competitiveness of a company is directly related to the level of tactical and operational optimization for manufacturing operations in the production systems. With a clear objective to reduce costs and production time, increase quality and responsiveness to new products, it becomes essential to implement sustainable practices in the production systems.

For organizations, the awareness that the planet's resources are limited is driving them to apply a sustainability performance framework [1]. With this performance framework, metrics to measure processes and manage social, environmental, and economic impacts, enables management to create enduring value for multiple stakeholders. Leading companies increasingly are examining the impacts of their products, services, processes, and other activities more broadly. They are seeking for more sustainable approaches to preserve resources, reducing waste and using available capacity in a more eco-friendly manner.

The present work addressed this major topic through the work conducted in sheet metal cutting Portuguese SME company. In this case study research work, the main focus derived from the aim to implement sustainable performance practices that support process assessment and optimization.

Typically, metrics must be developed to measure the impact that the inputs have on the processes and to translate the impact of the processes on goals and objectives of the organization. In the current case, the company aims to create a more efficient system to tackle much of the requirements proposed by the company and customer needs. The company presents a repetitive but not constant manufacturing production model. The services provided are constant, but their demand is fluctuating. The operations planning is complex and becomes necessary to sequence in detail (schedule) the production in order to optimize the consumption of resources, reduce waste and meet the operational needs of the company.

In order to improve performance metrics related with company's main processes, the company management established as main objective improve the production scheduling in critical processes along the production flow. Aligned with this management objective, the current research project defined as main goal the evaluation of the existing scheduling approaches and the assessment of the main efficiency indicators for these critical processes. As complementary task, the project aimed to validate the configuration data used from the current scheduling tool and perform a comparative analysis of solutions of other tools developed for the same purpose.

The following sections of this paper are organized as follows: section II presents the company and their main features; in section III the scheduling problem of the company is presented; section IV presents the scheduling computational tools that used in this study; section V makes analyses of the current production metrics of the company. Section VI shows and comments the computational study carry out and finally section VII reports some final comments and conclusions.

II - FACTORY PRESENTATION

In Portugal, the stainless steel industry is a market in expansion due to growing recognition of the qualities inherent to this type of material and possibility for industrial and domestic applications. In addition to solidification of the use stainless steel material in current applications, there is an increasing use of this material in other fields namely related to the sustainability issues due to its high reusability.

Founded in 1998, the case study company is a leading provider of products and services in the national steel industry. With the growing volume of business the company solidified its market position having at the present time, partnerships with major stainless steel producers worldwide. The company acquired in 2006 a new plant to increase the range of services and quantity of products available. With this acquisition, the company was able to acquire the necessary equipments for cutting and surface treatment of metal sheet, the main focus of this study.

According to the literature [2] we can characterize the production system as Table 1:

Table 1 – Company production process characterization

Parameters	Classification
Material Flows	• Continuous
Costumer relationship or Operating Metod	• Per Order and to Stock Manufacture
Produced quantities of one product	• Small Series (batch production) • Big Series (serial production)
Variability of Goods Produced	• Similar
Nature Products	• Discrete • Process
Characterization of Search	• Unpredictable demand Variable Search
Production Space	• Concentrated

The study addressed the company production system mainly one line of metal sheet cutting and a line for metal surface treatment. Although there are other production lines in the company, this initial study focused primarily on these two lines, namely due to its resource consumption and high efficiency dependency to good scheduling plans.

The company has a very linear production system organized as job-shop, with a small number of machines required to process the main components for the final products. The tasks have at most one operation on each machine, and the operations can be one of three types:

- Cut;
- Cut and superficial treatment;
- Superficial treatment;

The operative plan for each equipment is individual and distinct for each operational order as the restrictions (start and due dates are negotiated for each order individually with the customer and other resource usage restrictions).

Each machine (cut and superficial treatment) needs a constant human monitoring and intervention for the correct processing. Also is not scheduled correctly it produces significant waste and consumes significant amounts of wood packaging material.

III - PRODUCTION SCHEDULING

With the demand growth, a wider range of customers and increasing variety of products it has become visible the increase of complexity in the order management function. Nevertheless it is essential that each order has to be planned, processed, monitored and delivered on time in order to sustain the market position of the company. The correct order management function is essential to reduce any process errors, minimize production and delivery delays, efficient use of resources and minimize waste. Therefore proper scheduling planning and production control system plays a major role for the overall sustainability of the company.

Problem Description

The company has an information system for production management based in Manufacturing Resource Planning (MRP). The repository of information is comprehensive and has the necessary data from material needs for the production of manufacturing orders to the fixed stocks numbers of finished products.

In order to support the detailed planning (scheduling) the MRP system provides the data containing the information necessary for production of all manufacturing orders. This data is provided through a file that is send to the scheduling tool. All tasks information including start and due dates, precedence's, machines, quantities, etc., are included in this file. The scheduling system is only responsible for creating the scheduling or detailed plan.

The material flow for the studied process is described in the figure 1:

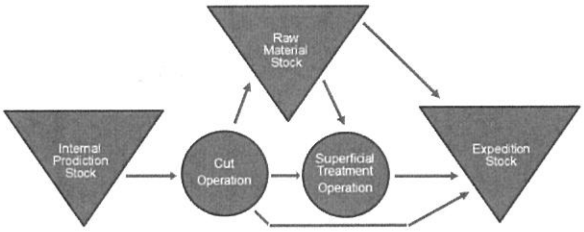

Fig. 1 - Material Flow

The material flow goes along most of the times the horizontal path, which is composed of four central steps: buffering of raw material, cutting operation, operation of surface treatment and final stock for shipment. In uncommon cases, there may be an intermediate buffer between the cutting and processing when a lot may only need to be cut and sent directly to the intermediate or final stock. Due to its characteristics, the material flow in this case could be considered as a Flow-Shop, since the products always follow a single path in its production process. Viewed in this way, there are several possible paths, and according to literature [3] since a Flow-Shop is a special case of a Job-Shop, it was considerer in this situation for simplicity a Job-Shop implementation. Therefore the problem in this case can be characterized as:

Table 2 - Problem Description

• A set of n jobs with one or two operations (multi-operation) available for processing at the moment according to the results of the MRP for a time span of seven days (approximately);
• The allocation of operations to machines is already pre-defined, therefore, our scheduling problem can be summed up in a sequencing problem;
• Preparation times for operations are dependent on the result, so are not included in processing time and are treated separately by the company for its scheduling software;
• The operations cannot be stopped;
• There are no precedence constraints between operations of different tasks
• Each machine can only process one task at a time;
• Each task can only be processed on a machine at a time;
• Are previously known attributes that describe the tasks;
• Each task corresponds to a product manufacturing linear structure;
• All tasks have equal priority order;
• The manufacturing environment is static, from one to three days;
• The company has in most cases as the objective function minimize the *makespan* (last proceeded task finish time) of the scheduling;
• Due to the high quantity of products produced by the company and the constant creation of new codes, the values of time are not completely correct, there is a high lack of time to set up mainly of machines;

IV - COMPUTACIONAL APLICATIONS

In order to deal and assess the scheduling problem, two scheduling applications were compared. The first proposed scheduling application is part of a project developed in Superior Engineering Institute of Porto ISEP [4] called MADScheGATS. The second application, Lekin, is a demo version of a application available in the internet [5]. At the end of this paper it is presented the conclusions achieved from the comparative analysis carried out to evaluate the detailed planning process in the company. In the conclusions it is also shown the advantages and the disadvantages of the current planning methodology namely to the business sustainability issues.

MADScheGATS

This software was developed in GECAD - Knowledge Engineering and Decision Support Group at ISEP. The name *MADScheGATS* derivates from *Multi-Agent System for Distributed Manufacturing Scheduling with Genetic Algorithms and Tabu Search*, and is a system where a group of distributed, autonomous and cooperating agents tries to solve scheduling problems.

This software allows to solve problems with a hybrid scheduling module in which a community of distributed, autonomous, cooperating and asynchronously communicating machines tries to solve scheduling problems.[4]

The *Multi Agent System* (MAS) uses a manufactory scheduling model of resources represented through agents and the tasks are performed in a distributed environment using cooperation and coordination among agents. [6]

The agent concept can be found in a large number of applications such as software engineering, artificial intelligence, human-computer interaction, distributed and concurrency systems, computer-supported cooperative work, control systems, decision support and electronic commerce.

The mains innovations in this software to the others is the integration of a Hybrid Scheduling Module that is a combination of Taboo Search and Genetic Algorithm based method and a mechanism for inter-machine activity coordination, with the objective of coordinate the operations in the machines using the constraints of their jobs. The system incorporates a module of dynamic adaptation to that is responsible of new jobs arrivals or cancelations. [4]

Lekin

The Lekin - *Flexible Job-Shop Scheduling System* is scheduling software developed at the Stern School of Business, NYU. Lekin starts as an educational tool for the introduction of scheduling and his features to the students.

Lekin application solves the scheduling problem after the individual introduction of all information for each task. It is an application with features similar to previous one having basically the same Dispatching Rules and Built-in Heuristics, but with the possibility of including the setup times matrix. Is free demo Software that can be found in the internet[1].

V - VALIDATION OF DATA ENTRY IN THE CURRENT SCHEDULING TOOL IN THE COMPANY

The company has a set of data associated to each product produced. This data is very important for the schedule as it contains the precedence, the machines used and the times of each operation (run times and setup times

Problem associated with the validation of the entry data

The input data required for the scheduling problem must be the most reliable as possible, in order to achieve valid results. Therefore, it was necessary to validate the data available in the company, before proceeding to the simulations of scheduling applications. In the following section it is presented a checking and validation of the operation times available in the data repository.

Time Determination

The study of time is related with the estimation of the interval of time required for a qualified person or machine to perform a given operation. The setup time is the time require from the last good piece produced from a lot (task) to the next good piece produced from the following lot (task).

The company have a large set of products; therefore it was necessary to create a product family scheme for the time definition. The products were grouped by is similarities in production and considering no setup times between each other.

In the current model of the company, the setup time for each operation was associated to the production time of a product. Since the setup time depends of the preceding operation, it was necessary to create a setup matrix between the different product families. After a measurement analysis of the different operations in the equipments and a comprehensive system analyses in the company, the setup matrix between all the families was determined.

With the purpose of validating the current production times present in the Information System in the company the produce times it was necessary to collect the measurements during the normal operation of the company for each product under study.

Time Results

With the time durations collected in the company it was possible to determine that the current data model of setup times wasn't accurate as it is possible to confirm in Fig. 2. This figure represents graphically the differences between the current setup times in machines A and B in study when the setup occurs from a product of family that we call "*a*" and other called "b". It is possible to state that in *Machine A* the setup average time has a level higher when compared with the measured values. In *Machine B* the opposite happens, the current values in average are lower than ones measured during the study.

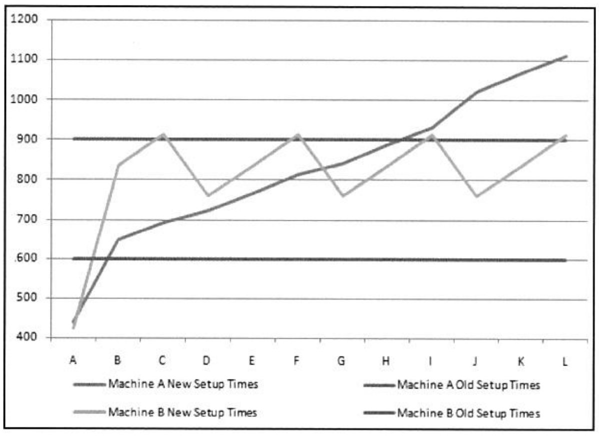

Fig. 2 - Setup Times Comparison

VI - COMPUTATIONAL (SCHEDULING) TOOLS EVALUATION

For the tests it was selected a 6 days' time horizon of production in the company in which was identified a set of 62 tasks for each plan of tests. For a correct assessment of the scheduling applications and evaluation of the results, a set of three types of simulation tests were designed.

Each set of tests have the exactly same Parameterization, Dispatching Rules and Objective Function. The difference between each set is the entry data treatment and setups. The three simulation test plans are presented in the next table.

[1] http://www.stern.nyu.edu/om/software/lekin/download.html *(Acceded in March 2011)*

Table 3 - Simulation Plans

Simulation Plans	Software 1		Software 2	
	Name	**Features**	**Name**	**Features**
Plan 1	*MASDSCHEGATS*	Runtimes and existing setup	*Lekin*	Runtimes and existing setup
Plan 2	*MASDSCHEGATS*	Execution times and certain existing setup	*Lekin*	Execution times and certain existing setup
Plan 3	*Lekin*	Execution times and certain existing setup	*Lekin*	Execution times and setup certain

Plan 1

Objective and Differences

The main objective is to have a first perception of how the programs behave with the tasks in the current conditions present in the company. It also enables a later analysis of the behaviour of scheduling operations using the values from the production times employed by the company and the values collected during the study. The simulation plan is different in terms of both processing times and setup.

Results

Table 4 - Results for Plan 1

Plan 1		
Software	*MASDScheGATS*	*Lekin*
Makespan	2549	2664
Max. Tardiness	0	0
Number of tardiness	0	0
Sum of tardiness	0	0
Time of Production	2689	2618

Results Analysis

The result analysis shows that there are no job delays in either tool, so we can consider that in this aspect the two applications are equivalent. On another hand, the total sum of production times is slightly higher in the case of MASDScheGATS, however, this late application provides the best solution for our objective function in about two hours apart, thus making this the schedule that best meets the requirements for this level of simulation.

Plan 2

Objective and Differences

The definition of this plan 2 intended to analyze a sample of orders using the times from the previous study, with the aim of studying if an adjustment of the current production times (at the moment used in the company) has in its scheduling application can result in lead time values closer to reality.

There is a fundamental difference that distinguishes this plan from the previous. With this plan, the production times are changed to reflect the process duration time more accurately. These latest values are closer to the reality of day-to-day work since, they have been collected during the operation period of the company.

Results

Table 5 - Results for Plan 2

Plan 2		
Software	*MASDScheGATS*	*Lekin*
Makespan	2543	2543
Max. Tardiness	51	0
Number of tardiness	1	0
Sum of tardiness	51,25	0
Time of Production	2364	2376

Results Analysis

With this plan, the application MASDScheGATS shows a lower value for the sum of production times. On the other hand, the values for the objective function are similar. In this simulation plan it is possible to identify a delay of 51 minutes, which means that the task would only be completed after the agreed deadline, that fact may bring cost penalties for the company. This situation poses to the decision-making agent, the necessity to consider what the most important factor is: the reduction in the sum of production times, or the delivery delay. From this analysis the decision-making agent should make is conclusions after deliberating what sequence to use.

Plan 3

Objective and Differences

The purpose of this third simulation plan is to assess how the setup matrix, as studied above, would interfere with the schedule for this company. Lekin program includes a parameter field for entering a setup matrix for each of the company's machines, thus enabling the creation of a schedule that tends to group the operations of the same family of products, creating a sequence production orders that enable the transactions to be processed more quickly and with less consumption of materials.

Results

Table 6 - Results for Plan 3

Plan 3		
Software	*Lekin* without setup	*Lekin* with setup
Makespan	2543	2543
Max. Tardiness	0	0
Number of tardiness	0	0
Sum of tardiness	0	0
Time of Production	2376	2296

Results Analysis

The purpose of this simulation plan is to analyse if a matrix of setup will decrease the times of production and of the objective function. From the results table 6 is possible to confirm that the sum of production time have decreased 1 hour approximately, thus giving importance to the need of including the more realistic setup times. On the other hand, the objective function was unaffected because in the studied scheduling plan it was a small number of tasks to do, and the gap between the operating times and the time available to perform the tasks was sufficient.

RESULTS ANALYSIS PLANS

Analysing the simulation plans under study with respect to the temporal distribution of these and the implications from use of the new determined production and setup times, it is possible to observe the difference in orders distribution in Table 7. Therefore, the change of duration for certain occasions caused a modification of the tasks distribution in the program MASDScheGATS, but keeping all other finishing at the same time. Also observed through the comparison of the different orders to be delivered, there is a constant trend of the application with the adjustment and anticipation of tasks, thus avoiding production bottlenecks and creating a more continuous production with fewer delays. In the case of Lekin it was found a slightly greater variation in the orders distribution in terms of the tasks sequence for the last days.

Table 7 - Orders Distribution

	Day	1	2	3	4	5	6	7
Plan 1	MASDScheGATS	12	11	7	8	17	7	0
	Lekin	13	10	7	9	15	8	0
Plan 2	MASDScheGATS	12	11	7	7	19	6	0
	Lekin	13	10	7	9	18	5	0
Plan 3	Lekin	13	10	7	7	18	7	0
Due Dates		8	15	7	6	14	13	1

In order to analyze the implications of the new processing and setup times the present work focused their attention in the Lekin results on each plan simulation and make comparison analysis.

Table 8 - Compiled results of simulation plans

	Setup and Production Times of in the Company	*Setup and Company New Times*	*Setup of the Company and New Production Times*
Makespan	2644	2543	2543
Tardiness Times Sum	0	0	0
Production Times Sum	2618	2376	2296

Table 8 confirms that the inclusion of both production times as well as the setup matrix has improved significantly the solution, allowing the purpose to maintain *makespan* goal constant but increasing the sum of production times in 5 hours and 30 minutes approximately. Thus, this justified the company's need to use the new production times and format their setup data set in matrix form.

With the results obtained from the 3 simulation plans, it is possible to make a global analysis taking into account two aspects: The comparison between the two scheduling applications; and the implications of the use of production times and setup calculated during this work comparing them against those that are employed by the firm. With respect to the first point, given the analysis of results previously made for simulation plans 1 and 2, it is possible to infer that the application MASDScheGATS showed better results than Lekin. Given the sustainability implications of the calculated times in the simulation results, it is clear to conclude from the results, that both the times of production and the setup matrix time should be updated and employed in the company for scheduling purposes.

From the result analysis found in production schedules within the company, it is clear that related with the issue of fixed setups, the company ends up creating a slack time in the process, i.e. when an order is released to manufacturing production it is always associated with a fixed setup time. This is prejudicial, since the machine operator groups the orders by product family, originating in the first place not a precise implementation of the proposed schedule by the application that in reality may prove unfavourable to the company, and secondly will result in a decrease in the actual setup times, creating slack in the production process.

VII - CONCLUSIONS

The Lekin, is a recent program and although the version being tested was a demo, presented a very interesting graphical interface, allowing easy insertion of the configuration data. Also noteworthy in this application was the rapid completion optimizations calculus. An important aspect to report from this program is the possibility to creating a matrix setup for each machine. This feature is fundamental in this company in order to take into account the considerable amount of the operating time that is spent on machine setups, which is non-productive time and varies from product to product. This process will pose an excellent opportunity to create an accurate time base for all setups and retrieve reliable metrics for resource consumptions and waste evaluation.

Related with the application MASDScheGATS, although this tool is still in development, the algorithms employed have demonstrated good performance in different simulations, obtaining results very similar and better than Lekin.

As a final comment, with this work the company can obtain a more detailed assessment with regard to its production process and a better understanding of the actual times of the process according to the present range of products. This assessment is extremely valuable in order to the continuous evaluation of the sustainable metrics that the company intends to achieve. Also with this research work, it was possible to derive improvement recommendations to the company that resulted in a more efficient scheduling process for the critical operations, ultimately enhancing the company business sustainability.

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BUSINESS SUSTAINABILITY 2.0

Management, Technology and Learning for Individuals, Organisations and Society in Turbulent Environments

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Chaos and Sustainability – the 2nd Order 2.0

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