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# An example of advanced planning and scheduling system (APS) implementation and operationalization

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*The objective of this study is to provide an overview of an advanced planning and scheduling system's (APS) implementation and operationalization process for elaborating a production schedule in a production environment similar to what is found in reality. The main characteristics and restrictions of a real production environment were thus considered, such as multi-level structure products, production routes with sequential, parallel and alternative operations, more than one resource per operation and alternative resources. In order to ensure the proposed objective's applicability, use of commercial APS systems available for industries was considered. A Brazilian APS system was chosen because it had an interesting alternative for application in developing countries. In terms of results, this study provides an overview of the main steps involved in the implementation and operationalization process of an APS system in an industry, providing an important indicator for choosing and using this sort of system.*

*Keywords: Implementation and operationalization; APS system; Advanced planning and scheduling.*

## 1. Introduction

The rapid changes which the world industry have gone through in the last few years – mainly regarding the competitive demands for a larger variety of products and the reduction in production time and costs, forcing it to deal with conflicting production requirements, such as the increasing diversity of manufacturing products, reduced production lots and compact manufacturing systems – have led the industrial environment to employ sophisticated computing tools for production planning and scheduling.

Due to the general use of these tools and operating research tools, this area of study has been commonly treated as advanced production planning and scheduling, and intends to employ sophisticated planning and mathematical methods to coordinate and optimize the use of all supply chain resources, including materials, production, labor, facilities and transportation, by means of optimization and decision-supporting systems (BOWERSOX, 2006).

Despite the wide applicability and competitive use potential of advanced planning and scheduling systems, only recently this type of system became feasible to be applicable to the industrial production areas, mainly due to the increased development of the personal computers, making the computer power available to industries, necessary to execute the planning and optimization methods.

This study intends to provide an overview of the implementation and operation processes of advanced planning and scheduling systems (APS), in order to elaborate the production scheduling in a productive environment similar to the one found in industries, taking into account the main characteristics and restrictions of a real production environment,

such as multi-level structure products, production route with sequential, parallel and alternative operations, more than one resource per operation and also alternative resources.

In order to guarantee a greater applicability, this study considered for use in this example the commercial APS systems, applicable to the industries. It was chosen an APS system nationally developed, intending to guarantee a greater applicability of national application of the proposed study. The example system was developed by employing national technology with the main proposal of a significant reduction in costs and the difficulties regarding the implementation and operation. This way, this study provides an overview of the main steps involved with the implementation and operation processes of an APS system in a specific industry, making an important indicator available to choose and use a system of this kind.

## 2. Advanced Planning and Scheduling Systems

In an industry, the production planning intends to create a disaggregated plan, which reflects the medium term plans, as well as the precise orders and predictions, determining the amount and when each product will be produced (SIPPER & BULFIN, 1997). The production scheduling is responsible for allocating all necessary manufacturing activities in order to accomplish the defined planning to the productive resources available across the time, following all the characteristics and restraints occurring in the production environment (GUPTA, 2002).

Traditional systems perform the planning and the scheduling in a sequential way, by means of a hierarchical procedure, from the most aggregated to the most detailed point. This way, the intrinsic relations between these plans are not considered, compromising its applicability to an actual environment. The traditional procedure composes the vast majority of managament systems (ERP) implemented in most of the companies nowadays. Most of the

companies remain at the margin of effective means of planning and, especially, production scheduling.

On the other hand, in the last decades, a great number of studies has presented elaborated planning and scheduling methods (ALLAHVERDI *et al.*, 2006) (GUPTA, 2002). Paradoxally, the application of the same to industries is still incipient, mainly because real problems are not considered or because the practical part of a specific production environment is not realized (MACCARTHY & LIU, 1993).

The APS systems allow for integrating the internal production activities of an industry or even all the activities involved in the production management, and contributing as an effective tool to the Supply Chain Management (STADTLER, 2005) (ECK, 2003) (SHAPIRO, 1999) (BALLOU, 1999).

A formal definition to an APS system can be found in the APICS dictionary (COX & BLACKSTONE, 2002), which states that APS systems are those using sophisticated mathematical methods to optimize or simulate system production scheduling involving finite resources. To this end, a great number of specific restrictions and characteristics of the productive environment is considered, thus accomplishing the planning and the scheduling in real time, supporting the decision in the production scheduling and the determination of feasible delivery terms.

The Institute of Operations Management (ENGLAND, 2002) complements that APS systems comprise a large variety of technologies and techniques, thus rapidly analyzing the implications of alternative decisions, highlighting consequences and problems. It enables the generation of optimal or near optimal plannings and schedulings. According to the institute, one can classify as an APS system all systems which:

- Consider simultaneously the material and the plant resources;

- Use optimization algorithms which incorporate the restrictions and the business goals;
- Are capable to provide real-time planning and scheduling, with fast regeneration following new changes and with capacity of simulating several situations in few minutes, by means of the resident memory;
- Help in real-time support decisions; and,
- Perform real-time available-to-promise scheduling.

According to ZATTAR (2004) the APS systems – in addition to considering the productive environment restrictions – also consider the restrictions from the necessary materials, thus planning further deliveries of raw material component production, in conformity with the needs to perform the production orders. Also according to CHEN & JI (2007) the APS systems represent an evolution of the traditional systems for the production planning and scheduling available into the current ERP systems. According to the authors, an APS system has more application potential to complex production environments, mainly those presenting one or more of the following aspects:

- Insertion in highly competitive markets, where the delivery time is critical;
- Complex itineraries – not repetitive – such as “job-shop” or “flow-shop”;
- Discreet products with a simplified material list;
- Possession of setup matrices;
- Need for overlapping and split;
- Complex resource allocation problems, such as different resource combinations to the production of a same service.

According to ECK (2003) APS systems represent a new and revolutionary step in the business and inter-business planning. It is revolutionary due to the technology employed as

well as to the production planning and scheduling techniques, which consider a large variety of productive environment restrictions, allowing for the production of an optimized planning. Among the possible expected benefits by adopting an APS system in a productive environment passible of implementation, one can state:

- Balanced use of resources;
- Increase in the resource worktime;
- Reduction in the resource setup time by means of more efficient scheduling;
- Reduction in the waiting time;
- Reduction in the lines before the resources;
- Reduction in delays and advancements;
- Reduction in the cycle time for production and delivery;
- Reduction in the need to employ overtime or outsourcing;
- Increase in the performance of the productive environment;
- Determination of the actual material and distribution requirements in terms of dates;
- Reduction in the production costs.

The current advancement in information technology was critical to make APS system development feasible, making possible:

- To avoid the combinatory problem through the computer implementation of mathematical methods of optimization or efficient approximation methods;
- To keep all the necessary information to elaborate planning and scheduling, resident in memory, by multiplying the calculation speed;
- To carry out, in a fast way, regenerations of the existing plannings;

- To make available intuitive graphic interfaces, thus facilitating the visualization of the plannings;
- To allow for the support to the decision, this enabling the analysis and comparison of situations and simulation;
- To make available real dates for deliveries; and,
- To cope with productive environments by using parametrization and personalization.

There are currently few scientific studies on the application of APS systems to national companies. PACHECO and SANTORO (2001) performed a study in six Brazilian companies, trying to detect deficiencies in the selective processes for APS systems. The selected companies presented characteristics which favored the use of these types of systems, mainly because they were inserted in highly competitive environments and demanding delivery trustability, reduction in the deadlines and in the inventories. AGUILAR (2004) addressed the functionalities in the APS systems and the potential gains obtained by the companies with the implementation of these applications. Therefore, the author has considered an international APS system, APO system by German SAP, applying to her study a semi-structured questionnaire in two companies using it, describing the factors which caused such companies to search for a APS solution, in addition to the changes occurred with the adoption of the tool and the achieved gains.

## 3. Implementation of an APS system in an example industry

In order to show the example of implementation and use of an APS system, it will be used – among several APS system suppliers – the APSX national system available in PLANNION (2008). The selected system had, as a main motivator, its easy access to national companies and the use of national technology in its development.

In order to elaborate the advanced planning and scheduling in a company, it is necessary to create a model for the production environment of said company, so that the planning and scheduling consider all the characteristics and restrictions of the studied production environment. This modeling is accomplished only once and will remain the same, while there is no change in the production environment. Following that, this modelling is registered in the APS system and will be available to make further planning and scheduling.

Many companies already have most information needed to create a model for its productive process registered in its management system (ERP) such as: the structure of the manufactured products, production time, precedence list for the production operations, and others. In case the company already has the available information, the same can be imported by the APS system. Otherwise, it will be necessary to register them in the APS system.

In order to have an overview of the modelling step of a productive environment to the implementation of an APS system, a hypothetical metal-mechanic industry will be taken as a example. It manufactures replacement pieces for all types of machines. Also, this company wishes to use the APS system to perform the planning and scheduling to a specific piece, known in this situation as “Replacement Piece”.

The first piece of information necessary to be collected is the structure to the production (list of materials) of the said piece. The *figure 1* presents the structure to the product “Replacement Piece”. It is noticed that, in order to produce the “Replacement Piece” it is necessary to count on a unit from the “Part 1”component, as well as on a unit from the“Part 2” component.

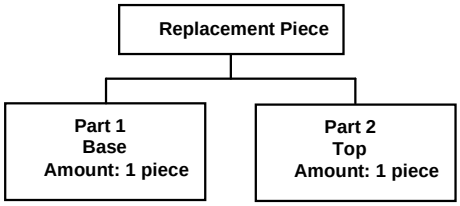


FIGURE 1 – “Replacement Piece” Product Structure.

Following that, it is necessary to know the necessary and available production resources to produce the piece, and also the work calendar that rules the production shift of this hypothetical company. Consider that this industry has a single Monday-through-Friday shift, starting work at 07 a.m., lunchtime at 11 and back to work at 1 p.m., finalizing the shift at 5 p.m. Consider that all production resources – human resources (labor) and also the physical resources (machines), adhere to this single work shift.

This example industry organizes its productive resources in five groups or types of different resources:

- **Cutting and sanding operators:** those apt to perform metal cutting tasks, either manually or in presses, and sanding on metallic surfaces, as well as welding;
- **Welding operators:** those apt to perform tasks involving metal welding;
- **Vise operators:** those apt to perform tasks involving pieces in a conventional vise;
- **Cutting press:** press-type machines which can be employed to perform metal cutting;
- **CNC vises:** those are programmable CNC-type, which can be employed to perform piece vising.

All production resources in this example company must be part of only one of the resource groups presented. Currently, this example industry counts on six production resources, described in the *Table 1*.

| Identifier Resource | Specific Abilities | Resource Group |
|---|---|---|
| Alex Silva | Piece cutting and / or sanding | Cutting and sanding operator |
| José Luiz | Piece cutting and / or sanding | Cutting and sanding operator |
| Ernandes Galba | Metal welding | Welding Operator |
| João Lins | Vising in a conventional vise | Vise Operator |
| Cutting Press | Piece cutting | Cutting Press |
| CNC Vise | Piece vising (programmable vise) | CNC Vise |

TABLE 1 – Production resources available.

The detailed analysis on how these resources work in the example industry showed that the “Cutting Press” machine does not have a dedicated operator. Therefore, whenever a task is allocated to the “Cutting Press” machine, a “Cutting and Sanding” operator must also be allocated to operate the “Cutting Press” machine. The “CNC Vise” resource has already a dedicated worker, so it is not necessary to allocate any operator. Regarding the productive process, the product “Replacement Piece” follows the production route according to *figure 2*.

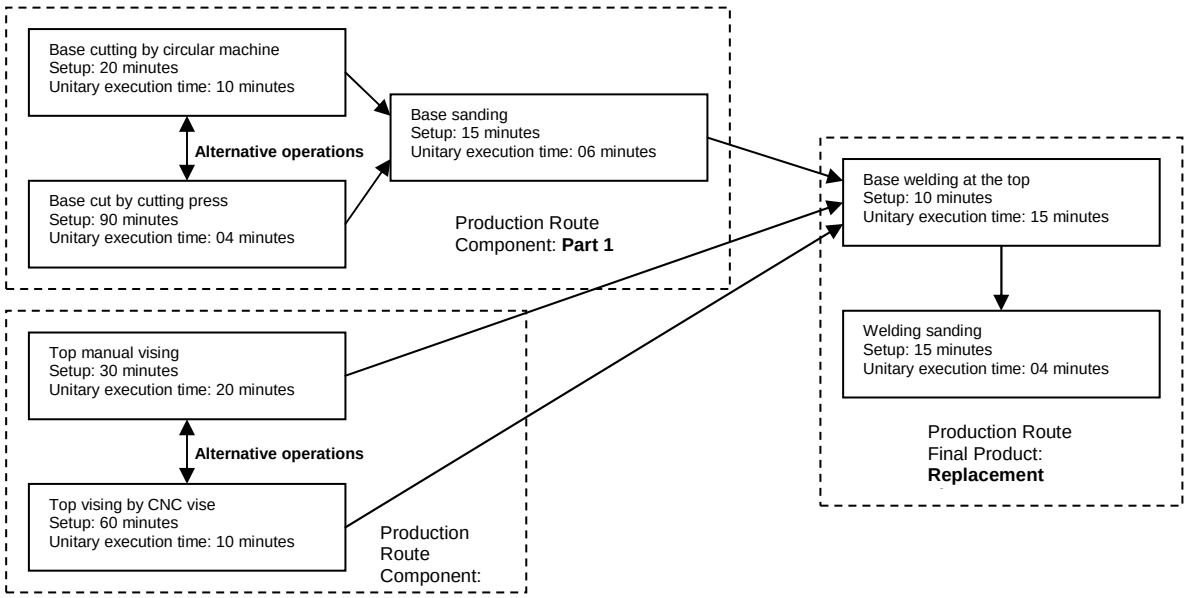


FIGURE 2 – "Replacement Piece" production route.

In *figure 2* each rectangle represents a productive operation. The dotted rectangles represent all the productive operations necessary to produce a part or component of the final product. The arrows between the operations represent the sequence among these operations,

that is, the route the product follows to be produced. The operations interconnected by double-tipped arrows are alternative operations, that is, only one of the alternative operations must be used. Also, the setup and the unitary execution time for each productive operation composing the route of the product to be manufacture were also informed.

It is necessary to further inform which types of resources will be necessary to perform each one of the productive operations. In the *table 2* it is specified which type of resources are necessary in each production operation.

| **Ident. of the production operation** | **Main resource group** | **Secondary resource group** |
|---|---|---|
| Base cut with circular machine | Cutting and sanding operator | None |
| Base cut by cutting press | Cutting and sanding operator | Cutting Press |
| Base sanding | Cutting and sanding operator | None |
| Manual top vising | Vise operator | None |
| Top vising by CNC vise | CNC vise | None |
| Base welding at the top | Welding operator | None |
| Welding sanding | Cutting and sanding operator | None |

TABLE 2 – “Replacement Piece” Product Structure.

These are all the necessary information to start the elaboration of the advanced planning and scheduling in an industry. With these pieces of information, it is possible to create a model of the productive environment in the advanced planning and scheduling system. Once the information is obtained, the next step is to transfer them to the APS system to create the productive environment model from this example industry. In the *figure 3* it is possible to visualize the interface with the user of the example APS system.

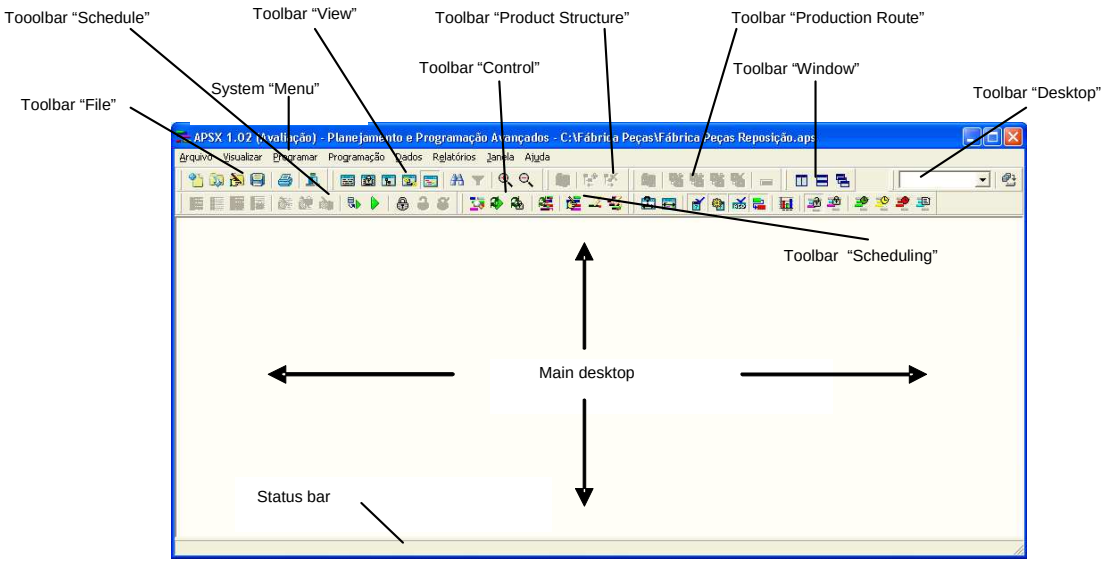


FIGURE 3 –APS system user interface.

All the necessary information registers to implement the example APS system are performed on the menu “Data”. The first action to be done in the APS system is to register the product “Replacement Piece” and the two metallic parts composing it. After, it is necessary to register the work calendar of the resources, according to the example company’s work shift. Then the necessary resource groups must be registered in order to produce the “Replacement Piece” in the simulated industry.

Still regarding the production environment registers, the production resources available in each resource group must now be registered. The next step is to register the productive operations which will be necessary to produce each part of the manufactured products. After the registration of the productive operations to each product, it is necessaary to inform the secondary resources, which will be necessary in each registered operation. By doing it, all the necessary data on the production environment are already informed, that is, a model of the productive environment was created in the APS system to the manufacture of the product “Replacement Piece” to this example industry. This model can be stored in a data file

which can be appropriately saved, and its use is allowed whenever a production scheduling is wished. In the example APS system, it is possible for the registered data from the production environment to remain stored in a database, enabling greater security and trustability in the system operation.

Once all the information on the production environment is registered, the structure of the product to be scheduled must be defined. To define the product structure is part of the definition process of the productive environment model. In order to facilitate this step, the example APS system makes a graphic interface available, which allows for a better visualization of the product structure being created. This interface is the specific desktop "Product Structure", which allows for the management of the structure of the products registered in the APS system.

In *figure 4* it is possible to view the desktop "Product Structure" with the product structure "Replacement Piece" defined. In addition to the structure, it is also part of the definition process of the productive environment the definition of the production route of the products. Therefore, the example APS system makes available a specific desktop, in which one can view and edit graphically the production route of a product. In *figure 4* it is also possible to view the desktop "Production Route" with the route to the product "Replacement Piece" defined.

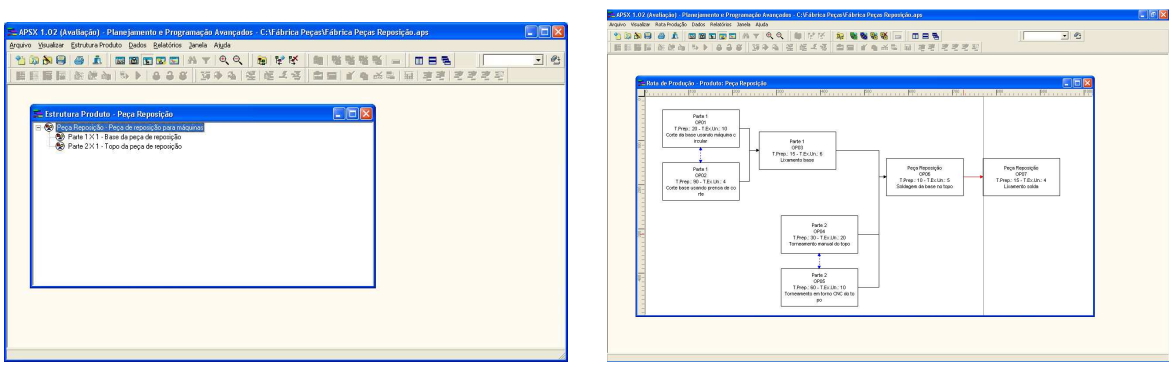

FIGURE 4 – Desktops "Product Structure" and "Production Route".

## 4. Operation of the APS system in the example industry

The operation of an APS system involves its routine use to the elaboration of planning and scheduling. The starting point to perform a production scheduling is to view which are the orders to be scheduled. This is done in the example APS system in the specific desktop “Orders to be Scheduled”, and it is possible to view and select the production orders which will be scheduled, as well as to alter information from these orders.

In order to illustrate the operation of the example APS system, ten production orders to the product “Replacement Piece” were scheduled. The production order registers are also performed from the data menu. In *figure 5* it is possible to view the specific desktop of orders to be scheduled. In this desktop, it is possible to select the production orders which will be scheduled, in addition to check the details of these orders.

The production scheduling will allocate, in the available resources, all the necessary operations to perform the selected production orders, respecting all the productive environment restrictions, thus providing a scheduling on a minute-to-minute basis to all resources composing the industry’s production environment. As an example, it was selected the first production order registered (marked in blue). Then it was performed the scheduling of the selected order, as shown in *figure 5*. After the production scheduling is done, the APS system informs the real delivery date scheduled.

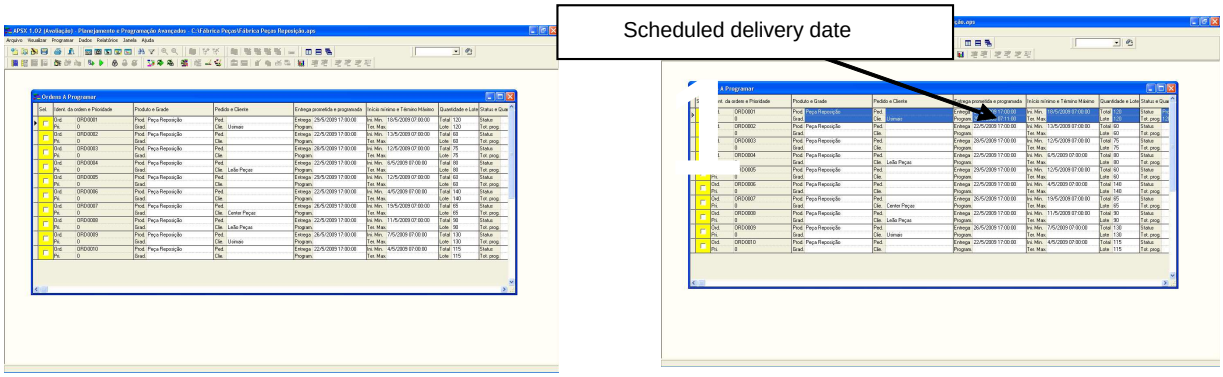


FIGURE 5 – Desktop “Orders to be Scheduled” with the orders to be scheduled and the delivery date of a scheduled order.

In order to operate the production scheduling in the productive environment, it is important to view the scheduling of the operations of the selected orders based on the work calendar for each production resource, following the product structure and its production route. Therefore, the example APS system makes available the desktop “Scheduling” in which it is possible to view the “Gantt Graph” to the scheduling generated, as shown in *figure 6*. In *figure 6* it is also possible to view the same interface when all orders to be scheduled are selected and the simultaneous scheduling of all selected orders is performed.

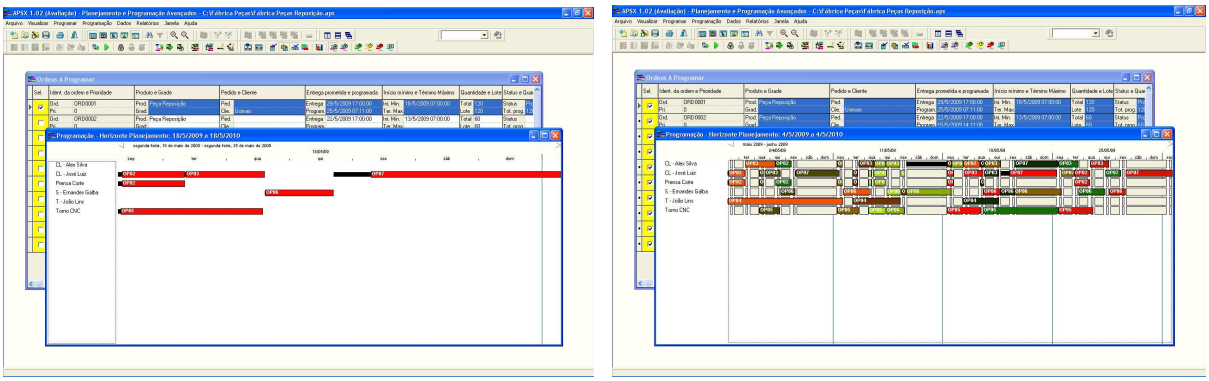

FIGURE 6 – Desktop “Scheduling” showing the scheduling of a selected order and the scheduling of all the selected orders.

The way in which all the production operations for each order will be scheduled will depend on the chosen scheduling rule. The scheduling rules are logical rules which determine the priority in which the operations will be allocated to the resources. Depending on the chosen rule the scheduling will be altered, and better or worse schedulings can be generated, depending on the situation of use.

For example, when the scheduling rule “Less operation time” is employed, a higher priority is given, in order to schedule the production operations which may have less time, then scheduling the operations with more time, and respecting, of course, the precedence restrictions among the operations. As for the rule “Ordering”, it prioritizes the scheduling of the operations according to the ordering of the production orders in the desktop “Orders to be Scheduled”. There are many scheduling rules available to be used with the example APS system. The choice for the better rule may vary according to the situation of the productive environment and the *mix* of products to be produced, so that it will be interesting that many rules be evaluated during the scheduling process for the production.

In the example APS system, it is also possible to employ mathematical optimization techniques in order to perform the production scheduling. When this option is selected, the APS system evaluates thousands of combinations for possible scheduling for the productive operations, searching for a scheduling which best meets a defined optimization objective. In the example system, the number of evaluated solutions will depend on the time made available to the optimization and also the performance of processing of the computer in which the system is installed. In the system used in this study, there are many possible objectives to be applied, in order to perform the scheduling such as: minimize the delay in the delivery of

all selected orders, minimize the total scheduling time of all selected orders, minimize the inventories in process or balance the use of the production resources.

In order to compare the several liberation rules or the selected optimization objectives in the generated schedulings, it is interesting to evaluate the performance of the production scheduling elaborated. Therefore, the example APS system has a tool which allows for the evaluation of several scheduling parameters from the productive environment. This way, one can quickly analyze the performance of several liberation rules or optimization objectives, and choose the one which best meets the specific objectives in your industry, as shown in *figure 7*.

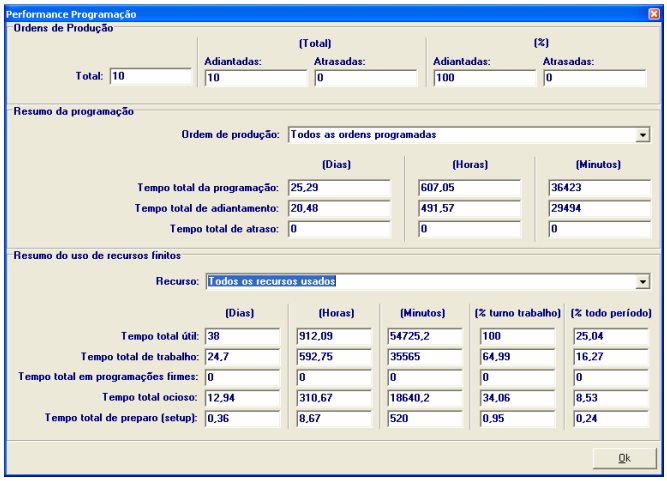


FIGURE 7 – Interface to evaluate the performance of an elaborated scheduling.

The scheduling method employed by the APS systems tries to meet all the restrictions to schedule the production of a production order so that one can guarantee that the scheduling generated is executable and can be applied in the production environment. However, it is common the presence of informal restrictions or even personal considerations on the production process which one wishes to occasionally consider in the production scheduling to be elaborated.

In the example APS system, it is possible to alter manually the generated schedule. One can alter the beginning, the end, the duration, the resource used as well as other

scheduling parameters for each production operation scheduled, directly in the “Gantt Graph” bars, or by using specific interfaces to this end.

When manual alterations are made in the scheduling generated by the APS system, it is common for these alterations to disrespect the restrictions from the productive environment. It is even possible to make the scheduling of the production unfeasible, mainly when it creates conflicts on the use of resources or disregards the precedence restrictions between the previous and following operations. Therefore, the example APS system makes available a scheduling regeneration method which corrects the conflicts without disregarding the alterations made.

Once a scheduling is arranged, it is important to have means to aid the information and control of this scheduling in the production environment to the resources involved with this scheduling. The example APS system has several reports especially developed to this purpose, enabling an online view of the productive environment and allowing for the production tracking. The *figure 8* shows an example of a managerial report from the detailed scheduling for the production orders.

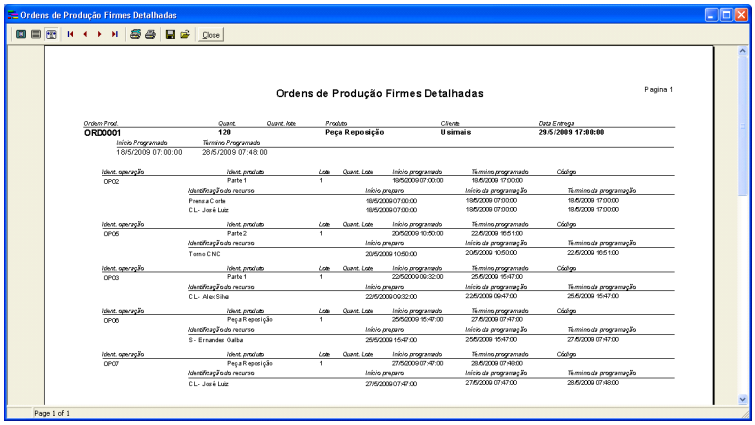


FIGURE 8 – Managerial report of the detail scheduling for a production order.

The evaluated APS system makes available several other functionalities, in order to facilitate the operation of an elaborated production scheduling, mainly intending a better interactivity with the decision maker, in order to obtain production plans with a better application potential to a specific production environment.

## 5. Final Considerations

This study intended to create an applicable example for the implementation and operation of a commercial APS system, thus illustrating – and even demystifying – this process. Threfore, a general example was based, similar to the possible industrial realities, employing a national APS system, mainly due to its application feasibility to national industries, in terms of costs and easy application.

The example created allowed for the evaluation of the core steps involved in the implementation process of a hypotethical mono-producing company. In a real company, it was possible to evaluate that the difficulties will be proportional, regarding deployment time, observing the real industry proportion in relation to the example employed.

As for the operation, it was verified, based on the scheduling generated to the example industry, that the APS system significantly empower the elaborated schedulings, concerning the scheduling performances – especially when optimization is used – and concerning the possibility of interaction with the production manager, allowing for the insertion of specific characteristics of the productive environment in the elaborated scheduling, making possible a greater application feasibility for the scheduling into a real production environment.

It was possible to evaluate that the APS system, in the daily elaboration process and control of the production scheduling, may be simple and intuitive, making possible for the production managers to work with scheduling having better efficacy, feasibility and trustability potential for the arranged delivery dates. It was also noticed that the detailed and

quick information that an APS system provides from the production scheduling allows for a better control and quick responses for the variabilities involved with the production, enabling the production managers to act pro-actively, facing the unexpected events from the productive environment, instead of reacting to these events when there are no alternatives to be taken.

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