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**Study of the implementation of an advanced planning and scheduling system (APS) at an  
electric equipment industry**

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**Abstract**

*This paper has the objective to propose the implementation of an advanced planning and scheduling (APS) system in an electric equipment industry. This industry is part of an intensely competitive market and manufactures a large number of products through a production-oriented process. It employs a high diversity of raw materials while working with tight deadlines and maintaining quality at low costs. In turn, advanced planning and scheduling systems (APS) seek to increase production environment efficiency. This can be achieved by employing sophisticated mathematical and planning methods allowing the effective use of production resources, and by taking into account resources' finite capacity, thus providing an effective alternative for improving industrial productivity. Results from analyzing the implementation and operation of an APS system in an electrical equipment industry verify the system's feasibility for the sector.*

*Key words: Systems implementation; Advanced planning and scheduling system (APS); Electric equipment industry.*

## **1. Introduction**

The nature of manufacturing management problems has undergone great change. From a relatively stable demand and technology environment, today we have an environment where product development cycles are reduced, product diversity increased and a focus on meeting client needs has become fundamental in a context where competition between companies is global. As a consequence, access to product diversity by part of the market has grown significantly compared to the recent past.

In response to the rapid changes and the new production scenario, manufacturing companies have seen themselves forced to accompany industrial development and revolutionize management of their operations, while also seeking to take advantage of the opportunities that stem from this new context. The new challenges for manufacturers, which became an organizational necessity until recently, are the reductions in production flow times, reductions in stock, improvements in product quality, better compliance with delivery deadlines, coordination of the supply chain's global demand and reduction in production costs (MARTINS and LAUGENI, 2005). However, obtaining higher performance levels is not feasible without considering elaborate forms of management. It is in this context that several types of support tools that employ sophisticated methods of logical and mathematical planning emerged aimed at providing the support needed to reach higher performance levels.

Among the main advances in elaborate management tools, advanced planning and scheduling systems (APS) have assumed an important support role for business operations because they permit a detailed generation of plans and schedules for operations, making it possible to coordinate and synchronize resource use. They try to optimize the use of production capacity while also trying to satisfy restrictions involved in the production environment. It also makes it possible to accompany production and identify and track the entire production process and lots in production, showing planning progress and its deviations in a detailed and simultaneous manner.

The electric equipment industrial sector has sought solutions to improve production efficiency. Inserted in a market with intense global competition, its manufacturing process deals with a large number of final products with process oriented production, employing a great diversity of raw materials with great delivery deadline, quality and cost demands. These factors have contributed towards electric equipment industries presenting difficulties in meeting growing market demands that involve reducing delivery and manufacturing deadlines, increasing efficiency in meeting orders and optimizing resource use, among others. In this environment, the elaboration of effective production plans could contribute towards achieving the competitive objectives desired by these industries. Thus, the objective of this study is to analyze the implementation process and use of an advanced planning and scheduling system at an electric equipment industry, aimed at presenting a feasible alternative to increase production efficiency for the industrial sector in question.

## **2. Advanced planning and scheduling systems**

Advanced planning and scheduling systems (APS) are computer programs aimed at associating diverse production variables seeking an optimization of organizational performance, and thus assisting in decision making. These systems are called advanced systems because they use sophisticated optimization methods and because they work with finite capacity. In other words, they consider resource restrictions and have optimization tools.

According to AGUILAR (2004), APS systems “try to simultaneously consider all significant restrictions for generating programs that maximize the company’s current business objectives, while supporting short, medium and long-term planning tasks.”

Through APS systems, it is possible to plan the entire supply chain, from suppliers to clients, permitting an analysis of production restrictions aimed at generating an optimized and feasible plan. This plan permits the elimination or reduction of certain production bottlenecks, such as unnecessary stock, excessively long lead times, time in line for products in the production process,

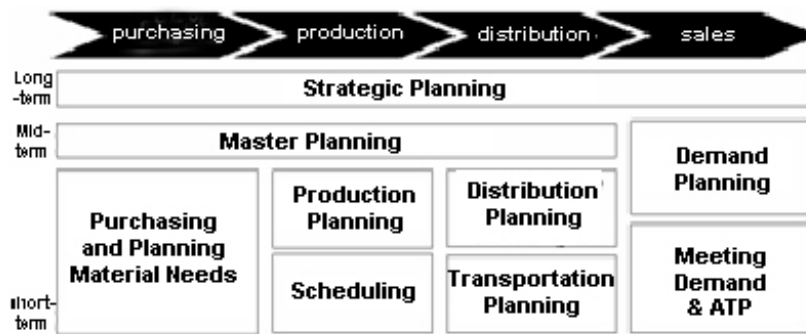
among others, increasing flexibility and speed in operations and allowing companies to create value (MEYR et al., 2002).

These applications allow planners to optimize the results of several variables that comprise the supply chain, such as determining the best means of transportation, assist in the accuracy of demand projections and help buyers strategically locate suppliers. Another competitive advantage brought by these applications is the speed in processing information, permitting quick answers to clients. According to ECK (2003), APS systems represent a revolution in organizational and inter-organizational planning because they use advanced technologies and planning and scheduling techniques that consider a broad range of production restraints for creating an improved plan, such as:

- Availability of material;
- Availability of resources and production capacity;
- Consumer service level (dates established);
- Safety stock levels;
- Production costs;
- Distribution demands;
- Fine production scheduling;

According to FLEISCHMANN et al. (2002), APS systems work with modeling, where reality should be considered in the simplest manner possible, without ignoring considerable restrictions, and alternatives, objectives and restrictions should be defined for several planning problems. This process may cause some difficulties due to the high number of possible alternatives in supply chain planning. In these cases, mathematical methods for operational research should be used to support planning, trying to define an optimal solution, or, for most combinatorial problems, solutions near optimal can be found using sophisticated logical algorithms.

According to MEYR et al, (2002), APS systems vary according to the companies that develop them, where the number of processes attended to and the functionalities present depend on each supplier of APS systems. However, it is possible to identify a common functional structure in APS systems, as can be seen in Figure 1.



**Figure 1.** Standard structure of advanced planning systems. Source: MEYR et al. (2002).

According to Figure 1, the main functionalities that can comprise an APS system are:

- **Strategic Planning:** refers to long-term decisions related to the market of operation and it may involve the identification of installations, products to be manufactured and sold, target markets, production processes, development of suppliers, plans for expanding production lines or the factory. This phase establishes the size and capacity needed to achieve maximum production levels and product distribution to clients. It is a directional phase to other levels of planning. The strategic planning horizon is normally measured in years (MEYR et al., 2002).
- **Master Planning:** defines the quantity of each final item to be concluded each week of the short-term planning horizon. The objective of this plan is to schedule the final items to be readily concluded when promised to clients and avoiding production overloads or idleness, so production capacity can be used efficiently and result in lower production costs (SLACK, 1997);
- **Demand Planning:** aims at minimizing installation overloads or idleness, seeking a reduction in production costs; proposes systemic changes in production capacity to meet peaks and moments of low expected demand, aimed at adjusting production capacity to aggregate

expected demand and obtain maximum production for the quantity of available resources, which is of utmost importance in times of scarce production resources (MARTINS & LAUGENI, 2005);

- **Production Planning and Scheduling:** responsible for generating a detailed schedule of the shop floor. The planning interval can vary from just a few hours to weeks, depending on the complexity of the industrial sector. Planning must be carried out for each production plant or unit, with details of the master planning. Production scheduling, in turn, must provide the beginning, end and production center for each production order to be executed. Furthermore, it also provides the sequence with which production orders must be executed at a certain production center. Production planning shall be done in a decentralized manner. In other words, besides master plan information, other important restrictions must be considered, such as the production capacity and personnel planning at each production unit (STADLER, 2002b).
- **Planning Purchases and Material Needs:** calculates the needs and dates for material purchases according to the phase of secondary demand plans for components and other parts based on calculations using primary demand and aimed at supporting the supply function decision process within the company (STADLER, 2002c).
- **Planning Distribution and Transportation:** this is divided into a transportation system and a distribution system. The transportation system connects the entire supply chain related to the company, from supplier to the client. This system presupposes an integration of purchasing, transportation, production and stock processes for effective management of the supply chain. Decisions regarding transportation orders, that is, decisions about the quantity, origin and destination of cargo are transport system tasks. The distribution system encompasses the flow of different products from different distribution centers to a multiple and variable ratio of clients (FLEISCHMANN, 2002).

The main difference between traditional production control and planning systems and advanced planning and scheduling systems is in the use of mathematical and/or logical optimization methods and the joint consideration of material planning and resource scheduling considering finite capacity. Traditional planning and control systems only plan materials (MRP) or do this planning separated from the scheduling of resource use, not considering resources as finite and not permitting an appropriate synchronization between these two plans, resulting in unfeasible or inefficient planning (AGUILAR, 2004).

Seeking the synchronization of material planning and the detailed scheduling of production resources, advanced planning and scheduling systems employ sophisticated computer algorithms for elaborating production planning and sequencing as well as optimizing mathematical methods. This results in more balanced resource planning and scheduling, maximizing production capacity as a whole (STADLER, 2002b).

With the application of advanced planning and scheduling systems, it is possible to obtain significant increases in production resource allocation efficiency, through an improved sequencing of each resources' activities, permitting greater efficiency in production resource allocation, machine setup economies, reduction in in-progress stock levels and consequently time in line prior to operations, reducing the formation of production bottlenecks, reducing the time the product spends in the production environment, reducing cycle time, permitting greater control of production, reducing planning and production failures, among other efficiencies that will have a direct impact on production cost reductions and increases in business competitiveness (AGUILAR, 2004) (STANG and ARCURI, 2003).

Pressure for greater competitiveness has made companies invest in systems that permit greater coordination of the supply chain in the search for synergy and chain optimization (PACHECO and SANTORO, 2001). Optimization of the supply chain is related to the following objectives (GOMES & RIBEIRO, 2004), (STADLER, 2002a) (ECK, 2003):

- Maximize and make real potential synergies between production chain parties to satisfy the final consumer more efficiently by reducing costs as well as by adding more value to final products.
- Reduce costs by decreasing information and security transaction volumes and transportation and stocking;
- Diminish the variability of the demand for products and services, among others;
- Take the right product to the right place at the lowest cost;
- Add value to products by creating customized goods and services and the joint development of distinct competencies by the production chain and by efforts so suppliers and clients can increase productivity;
- Reduce stocks and diminish the number of suppliers.

Despite the range of applications for APS systems, this study focuses on the study of production planning and scheduling at electric equipment industries, limiting itself to analyzing that functionality in this study.

### **3. Installation of an APS system at a manufacturer of electric equipment**

This study used a national advanced planning and scheduling system available on PLANNION (2009). The analyzed APS system is specific for the production planning and scheduling areas and it has all the characteristics of an APS system for this purpose, as described by TEIXEIRA JR. (2008).

The analyzed system is capable of scheduling the production of production resources in short intervals of time, considering the vast majority of production restrictions that may occur in a typical production environment, such as finite resource capacity and real work calendar. It employs optimization methods to generate schedules that optimize the use of production resources and minimize delays and other production costs. It also enables management of all materials and raw

materials employed in the production process and deals with internal and external logistics in order to increase the efficacy of the relationship with clients and suppliers.

The company studied operates in the electric equipment manufacturing sector for potentially explosive and weatherproofed areas. The company concentrates its operation in a single plant in the city of São Paulo, unifying the production and administrative processes. At present, the company has approximately 90 employees including shop floor and administration areas. The electric equipment produced by the company includes: light fixtures, projectors, junction boxes, outlets, plugs, push buttons, standardized panels and other electric equipment and accessories.

The studied company's products are manufactured according to the norms of the Brazilian Technical Norm Association (ABNT). The company's quality assurance system is certified by NBR ISO 9001/2000, and DNV NORSE VERITAS which is recognized abroad (RvA). The company is qualified to supply most chemical, petrochemical and steel industries in the Brazilian industrial park. The company has more than 30,000 products considering the possible variations in painting, threads, holes and other options offered or requested by clients. However, the study shall encompass only the existing models of each product, thus disregarding the possible variations.

In face of the large number of products manufactured by the analyzed company, the decision was made to initially run a pilot implementation project to assess the performance presented by the APS system analyzed in this pilot study. Three families of products were selected for this, as described below:

The selected families of products were:

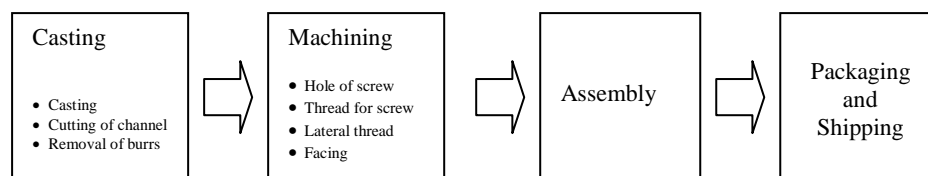
- **AR** – Junction box (*alphalete*) and derivation for industrial electrical installations. The body and lid to these *alphaletes* are in cast aluminum alloy with a natural rubber seal, generally used in metal or plastic conduit installations. They can be manufactured in eight construction formats (E, C, T, X, LL, LB, LR and TB) with standard NPT or BSP threads (*Figure 2a*).

- **AW** – Explosion proof light fixtures, recommended for environments with flammable vapors or gases, work with solvents, chemical and pharmaceutical industries, etc. With the device’s armored system, any explosion that may occur in its interior will not present any risk to the environment. It is manufactured in four models: hanging, ceiling, and 45° and 90° wall light fixtures. The AW family has two segments: AW-10 to AW-17 and AW-30 to AW-37, where the size of the light fixture cubes is the difference between these segments (*Figure 2b*).
- **AWR-14** – Rectangular or square, explosion proof junction boxes manufactured in cast aluminum alloy and copper free. NPT or BSP threaded inputs, reinforced fixation ears and lid fixation using bichromatized or stainless steel screws (*Figure 2c*).



**Figure 2.** Families of products considered in implementation of the pilot

The company’s production process basically consists of four production stages, as seen in *figure 3*, Casting, Machining, Assembly and Disassembly and Shipping. Regardless of the family of products considered, they all go through these four stages of production in sequence. What vary are the characteristics of the production operations in each stage of the process.

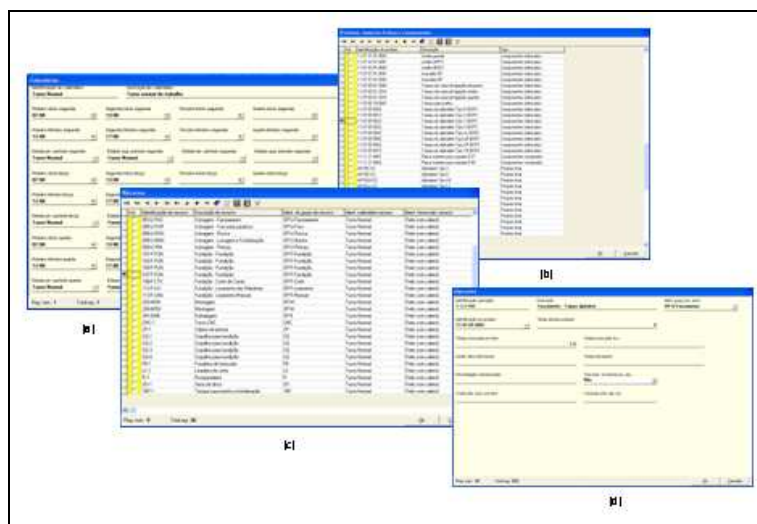


**Figure 3.** Production process of the studied company.

Casting is the manufacturing stage where a metal or metal alloy, in liquid state, is poured into a mold with the shape and measurements that correspond to the piece to be produced. The company’s

Casting Sector also absorbs other activities like cutting the channel, removing internal burrs and removing external burrs. In the machining stage, the piece is machined for making dimensional adjustments or even shaped mechanically so the final shapes and sizes are obtained. The assembly stage consists of controlling and monitoring processes according to product availability and third party delivery deadlines (suppliers or products belonging to clients) as per planning meetings and actual delivery. Finally, the Packing and Shipping stage consists of the proper packing of manufactured products in order to maintain their physical and functional characteristics during the merchandise storage, shipping and transportation period.

Installation of the APS system began with registering the studied company's production environment. These registries involved the work calendar, manufactured products, components and materials used in manufacturing, available production resources, production stages and times involved with production of each product in each stage. *Figure 4* shows some registry screens of the analyzed APS system.



**Figure 4.** APS system registry screens, Registry of Calendars (a), Registry of Products and components (b), Registry of Resources (c) and Registry of Operations (d).

After all the basic registries have been made, it is necessary to register the structure of the manufactured products. This is done in the Product Structure screen, as seen in *figure 5*.

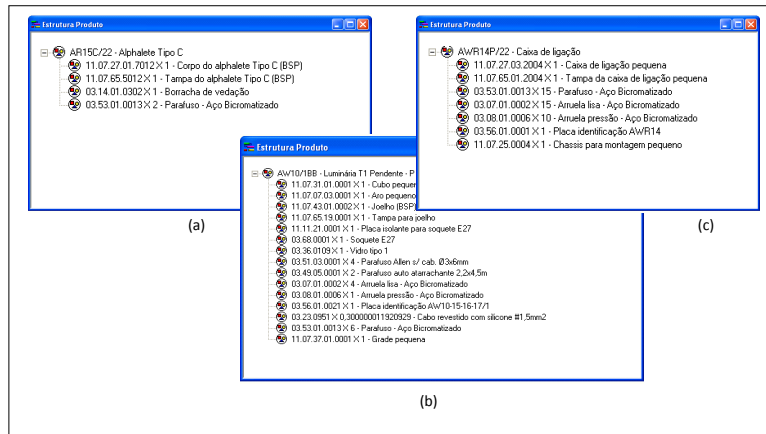


Figure 5. Registry of product structures AR (a), AW (b) and AWR (c).

Finally, it is necessary to register the production routes for each manufactured product. This registry is done on the Production Route screen. *Figure 6* shows the production route registry for a product from the AR family.

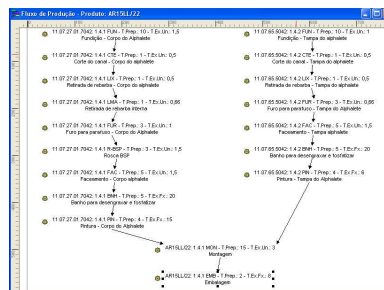


Figure 6. Production route registry screen.

Once the registries have been completed, the APS system is ready for operation. The production environment registries shall only be carried out during the implementation process and will be available throughout the entire period the system is in use. They shall only be reviewed when there are changes in the company's production environment. In order to assess implementation of the APS system at the studied company, production order arrivals for a two-week time horizon were simulated. The generated production orders tried to encompass all registered products and reflect

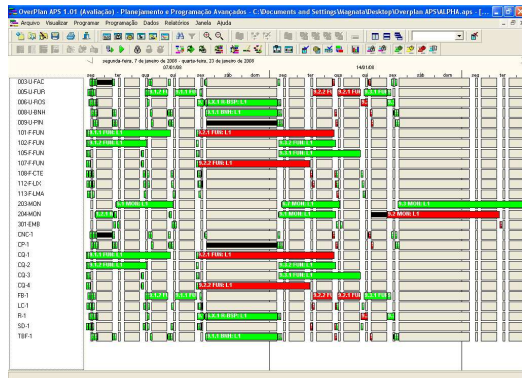
the type of orders that normally occur at the studied company. In *figure 7* it was possible to visualize the selection process for an order to be scheduled.

Identificação de ordem	Pedido a Gravar	Pedido a Cliente	Tempo restante a programado	Inicio máximo a Termino Máximo	Quantidade a Lote	Status a Modo Programação
0001	Prod. 449144190	Prod.	Emprego 15/1/2008 18:00:00	18 Jan. 6/1/2008 08:00:00	Lotiz. 60	Seleto
0002	Prod. 449144192	Prod.	Emprego 14/1/2008 18:00:00	18 Jan. 6/1/2008 08:00:00	Lotiz. 20	Modo: Man cabo-possivel
0003	Prod. 449144140	Prod.	Emprego 11/1/2008 18:00:00	18 Jan. 6/1/2008 08:00:00	Lotiz. 80	Seleto
0004	Prod. 449144140	Prod.	Emprego 11/1/2008 18:00:00	18 Jan. 6/1/2008 08:00:00	Lotiz. 20	Modo: Man cabo-possivel
0005	Prod. 449144192	Prod.	Emprego 11/1/2008 18:00:00	18 Jan. 6/1/2008 08:00:00	Lotiz. 20	Seleto
0006	Prod. 449144192	Prod.	Emprego 11/1/2008 18:00:00	18 Jan. 6/1/2008 08:00:00	Lotiz. 20	Modo: Man cabo-possivel
0007	Prod. 449144192	Prod.	Emprego 14/1/2008 18:00:00	18 Jan. 6/1/2008 08:00:00	Lotiz. 40	Seleto
0008	Prod. 449144190	Prod.	Emprego 11/1/2008 18:00:00	18 Jan. 6/1/2008 08:00:00	Lotiz. 20	Modo: Man cabo-possivel
0009	Prod. 449144190	Prod.	Emprego 11/1/2008 18:00:00	18 Jan. 6/1/2008 08:00:00	Lotiz. 40	Seleto
0010	Prod. 449144190	Prod.	Emprego 11/1/2008 18:00:00	18 Jan. 6/1/2008 08:00:00	Lotiz. 20	Modo: Man cabo-possivel

**Figure 7.** Orders to be scheduled screen.

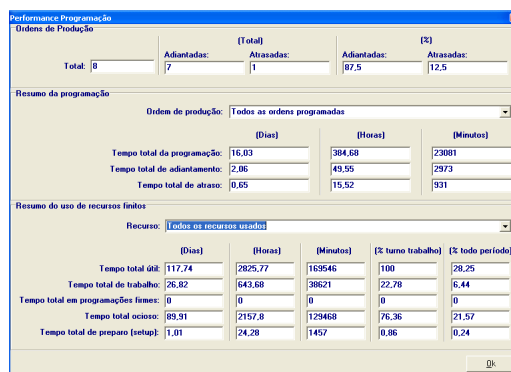
The study of system operations consisted of scheduling production orders that were generated for each simulated day of order arrivals. Production scheduling allocates production operations to produce each selected order to the production resources needed, respecting the resource use schedule. The system has several scheduling rules that can be applied to diverse possible situations. The choice of the best scheduling rule for a specific production environment shall be analyzed at the moment of system application. Besides the available scheduling rules, the studied system also has an optimization method that seeks to achieve a more elaborate schedule according to defined production objectives by employing a calculation time for optimization.

The “EDD” scheduling rules was chosen for scheduling the selected orders due to calculation speed and its fitness to how the company currently conducts its scheduling. In *figure 8* it is possible to visualize the APS system scheduling screen with the scheduling generated for several work days at the company according to the "EDD" scheduling rule. The scheduling screen has a "Gantt Graph" format where, on the left, arranged in each line, we have the production resources available at the company, and on the right, the bars represent production operations or hours without work, scheduled for each corresponding resource and where bar length is proportional to scheduled duration.



**Figure 8.** Scheduling screen with the system’s “Gantt Graph”

The analyzed APS system offers a tool to assess production scheduling performance elaborated considering its diverse scheduling parameters and the production environment. It was thus possible to analyze that among the scheduled production orders, seven are ahead of schedule and only one is late. The scheduling summary indicates the time needed to comply with the scheduled production orders, where the total ahead of schedule time (2.06 days) and the total late time (0.65 day) are highlighted. It is also possible to analyze scheduled orders individually, thus providing more specific planning information. The production resource use summary provides data on the allocation and use of the industry’s production capacity, showing, individually and overall, work time, idle time and resource set up time, as can be seen in *figure 9*.



**Figure 9:** Scheduling performance analysis

As can be seen in the scheduling performance analysis, the “EDD” scheduling rule generated a schedule with a late order. This information permits the manager to conduct proactive work in the

production environment to reverse this delay, such as by reallocating resources or work in the form of overtime, thus avoiding delays in order delivery to the client. This type of advance notice of problems is not possible without the support of an APS system since delays are only perceived when they occur.

Despite the advantage the APS provides by giving advance notice of possible problems that occur in the production environment, it would be even better if the system could solve the problem without any need for external interference by the manager. Thus, the optimization method was applied to the assessed APS system with the objective of minimizing the delay of all orders, aimed at finding a production schedule without late production orders. It is important to underscore that the optimization method needs time for calculations, where the optimization performance will be influenced by the calculation time made available. For the purposes of this study, 10 minutes were made available for calculation. With that amount of time, the optimization method was able to schedule the orders in a manner that all orders were scheduled without delays.

#### **4. Analysis of Results**

The studied company currently uses manual production planning and scheduling through meetings with those in charge of production sectors and sales and purchasing managers. This manual process frequently does not satisfy production objectives or meet signed orders causing constant wear with clients and reduced production performance levels. Implementation of an APS system shall represent an effort for this company in the sense of integrating and improving generated production scheduling performance as well as improve production environment productivity.

The analyzed APS system met all characteristics and particularities of the industry's production environment allowing the implementation to reflect the actual production environment of the company in question. The APS system enabled the information related to projections of delivery dates for scheduled orders to be available ahead of time. This information is of utmost importance

for the industry studied so preventive actions can be taken to anticipate possible production problems.

Tests run demonstrate that the analyzed APS system proved able to deal with complex production environments and with a mix of varied products. The main benefits observed from studying the implementation of the APS system at the company were:

- The possibility for simulation and projections of different demand scenarios and analysis of the production environment's capacity to meet them according to the study of generated schedules;
- Reduction of informal planning and scheduling systems and their unification into a single system, operated by a trained and instructed individual;
- Availability of an efficient and reliable system for planning involving the planning of purchases, hiring and firing of personnel, equipment needs and other aspects related to the production environment.
- Improvement in production master plan accuracy by determining final product quantities and items to be produced, resulting in better control in purchasing and lower raw material and component stock;
- Availability of a detailed schedule of production resources permitting an improved attribution of daily work activities and better control in the execution of these activities;
- Reductions in lead times to meet orders. These are a growing demand among clients who want increasingly shorter deadlines and actual compliance with them;
- Reduction of effects in the production environment resulting from changes in orders since the system offers the possibility of making adjustments in the defined scheduling or of generating a new schedule in a short period of time, thus reducing the impacts from changes in signed orders;
- Reduction in resource idleness involving machines, equipment, labor, inputs and other resources, or in taking advantage of equipment idleness where preventive or corrective

maintenance can be scheduled, as well as modifications, tests, reallocation of labor to other activities and of inputs that can have their consumption reduced during this period;

With regard to difficulties encountered in the study of this APS system implementation, the following stand out:

- Data accuracy in face of the multiple variables inherent to the production process and lack of standardization and updated information, there could be asymmetry of data;
- Complexity of the production environment such as product mix, production operations, human and production resources, among others;
- Time spent on implementation, the multiple and complex production environments demand a lot of time from managers and schedulers related to database registration, tests and pilot programs;
- Dynamism of the production environment that demands the continuous updating of registries.

It was possible to overcome the difficulties found during implementation and the benefits ascertained from using the system created motivation at the studied company to expand implementation of the pilot project for other manufactured products.

## **5. Conclusion**

The objective of this paper was to study implementation of an advanced planning and scheduling system at an electric equipment industry aimed at creating an understanding of the implementation process and an initial assessment of software applicability potential in the referred to industrial sector, highlighting the possible benefits resulting from the use of an advanced managerial tool to schedule production.

The analyzed APS system made it possible to consider all the characteristics and particularities of the studied company in the system. The benefits ascertained with system implementation and operationalization suggest the effectiveness of applying the APS system in the industrial sector in

question, making it possible to conduct more detailed control and scheduling of production resources as well as maintain an online analysis of performance and progress of elaborated scheduling. This permits a reduction and better monitoring of order delivery times and more efficient management of the production environment as a whole.

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