INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br v. 5, n. 4, October - December 2014
ISSN: 2236-269X
DOI: 10.14807/ijmp.v5i4.239

AN OVERVIEW OF THE ADVANCED PLANNING AND SCHEDULING SYSTEMS

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Submission: 10/06/2014
Accept: 24/06/2014

ABSTRACT

Currently, the activities of the planning and control of companies are becoming increasingly complex and the managers of this area are constantly pressured to reduce operating costs, maintain inventories at adequate levels, to meet fully the demand of customers, and to respond effectively to the changes that occur. The planning and scheduling task is important for most companies, so according to some authors, there is a need for further analysis of the practical use of production planning and control systems. Within the context of production planning and control systems developments, in the 1990s were launched the APS systems, which represent an innovation when compared to their predecessors. This paper intended to provide through a literature review, the

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concepts, structure, capabilities, implementation process and benefits of using APS systems in the company's production planning and control. The main contribution of this research is to show a strong conceptual understanding regarding APS systems, which can be used as a solid theoretical reference for future researches.

Keywords: Advanced Planning and Scheduling, Production Planning and Control, Literature Review.

1. INTRODUCTION

According to Porter et al. (1996), Production Planning and Control (PPC) is generally used to describe collective processes of capacity planning, material requirements planning, shop floor control, works order release and control. The PPC seeks to align the supply of a manufacturing company with the demand for its products, while maximizing its performance within the framework of the company competitive stance in terms of quality, cost and delivery (MUKHOPADHYAY; DWIVEDY; KUMAR, 1998). PPC plays an important role in competitive environments, responding immediately to achieve higher service level of performance, better resource utilization, and less material losses (AL-TAHAT; BATAINEH, 2012).

Production Planning and Control systems (PPCs) are the central corporate control mechanisms that relate the production and logistic performance of a company with customer demands. Its main task is to plan, initiate and monitor manufacturing company products delivery, and, in cases of unforeseen deviations, to adjust the progress of orders or production plans (WIENDAHL; VON CIEMINSKI; WIENDAHL, 2005). PPCs have an important role in the continuous search for improvement in production resources use (RODRIGUEZ; COSTA; DO CARMO, 2013) and aim to plan and control production so the company achieves the production requirements with the highest possible efficiency (FERNANDES et al., 2007).

PPCs are models used for planning and controlling physical transformation processes in production systems (HELBER, 1995). The use of these softwares has enormously increased in industrial environments since the 1980s (LUCZAK; NICOLAI; KEES, 1998). They represent a competitive advantage source for

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companies that search competence in PPC area (MUKHOPADHYAY; DWIVEDY; KUMAR, 1998).

According to Steger-Jensen et al. (2011), the computerized PPCs were gradually developed in the last 30 years, since the systems Material Requirements Planning (MRP), Manufacturing Resources Planning (MRP II), Enterprise Resources Planning (ERP) and Advanced Planning and Scheduling (APS). These continuous developments provided substantial improvements in PPC area of companies (NYHUIS; WIENDAHL, 2004).

In the 1990s, a new breed of concepts called APS systems emerged (ÖZTÜRK; ORNEK, 2014). APS systems are a set of applications used for managing three domains of supply chain operations: planning, programming and execution (SETIA; SAMBAMURTHY; CLOSS, 2008). APS systems are considered as an effective approach for generating an optimized production plan considering a wide range of constraints, including raw materials availability, machines and operators' capability, service level, secure stock level, costs, sales and demand (CHEN; HUANG; LAI, 2009). According to Brun et al. (2006), APS systems represent the most relevant innovation in the world of manufacturing since the introduction of MRP systems in the 1970s.

The use of APS systems as support tools for decision making in the production planning and control of companies is growing at the global level. Based on these affirmations and its increasing relevance, the aim of this paper is to present a literature review on APS systems, in order to provide to the reader an understanding of the concepts, structure, integration with other production planning and control systems, implementation process and benefits that their use provide to the companies.

2. METHODOLOGICAL PROCEDURES USED FOR DEVELOPING THE RESEARCH

The methodology used for the development of this paper aims to get results capable of supporting the construction of a better knowledge on APS systems.

Published papers in scientific journals indexed in databases SCIELO, SCOPUS and Web of Science were analyzed. For this research, were revised mainly

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papers published in scientific journals, because they have more careful selection and assessment than papers of conferences and symposiums (CARNEVALLI; MIGUEL, 2008), and are considered researches of highest level, both for gathering information, and for dissemination of new results and discoveries (NGAI et al., 2008). Some information from papers published in conferences were obtained, because although they have less relevance, certainly can have important issues (BORTOLLOSSI; SAMPAIO, 2012).

For selecting the publications of interest, they were searched by title, abstract, keywords, irrespective of the period of publication, the following terms: Advanced Planning and Scheduling, and Advanced Planning System*. Subsequently proceeded to the reading and analysis of abstract and introduction of the papers found, by selecting those with relevance to the research objectives.

With respect to nature, this work is classified as a basic research, considering that according to Turrioni and Mello (2012), seeks to add new ideas favorable to the advancement of knowledge, involving truths and universal interests, without the worry of use them in practice. Based on its goals, this work is classified as an exploratory research. According to Forza (2002), the purpose of exploratory research is to build an initial idea about a topic, providing the basis for more detailed studies, in order to improve the techniques currently available. Regarding the technical procedures used to carry out this paper, it was conceived through bibliographical research. The bibliographical research allows the identification of the state of the art and possible gaps that may exist, and identify opportunities for new contributions to the topic under study (VILLAS; SOARES; RUSSO, 2008).

3. ADVANCED PLANNING AND SCHEDULING: AN OVERVIEW

3.1. General characterization

According to Stadtler (2005), APS systems are based on the principles of hierarchical planning and make extensive use of solution approaches known as mathematical programming and meta-heuristics. The main APS systems ability consists in finding the optimal resource selection for operations, operations sequences, allocation of variable transfer batches, and schedules considering flexible flows, resources status, capacities of plants, precedence constraints, and workload balance (GEN; LIN; ZHANG, 2009). Unlike other systems, APS does not assume that

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capacities are infinite, that all customers, products and materials are of equal importance, and that certain parameters, such as lead times, can be fixed (DAVID; PIERREVAL; CAUX, 2006).

APS systems provide analyzes for guiding the provision of supply, manufacturing and logistics operations and determine the impact of the unique business rules and capacity constraints in programming (SETIA; SAMBAMURTHY; CLOSS, 2008). APS systems have improved the integration of materials and capacity planning, bridge the gap between the supply chain complexity and the daily operative decisions (HVOLBY; STEGER-JENSEN, 2010). APS systems are considered as an effective approach for generating an optimized production plan considering a wide range of constraints, including raw materials availability, machines and operators capability, service level, secure stock level, costs, sales and demand (CHEN; HUANG; LAI, 2009).

According to Günther and Meyr (2009), APS systems represent successful applications of supply chain management, and are related to support activities and decision making at the strategic, tactical and operational levels. By APS systems companies can optimize their supply chains, reducing costs and inventory levels, improving product margins, and increasing industrial yields (LEE; JEONG; MOON, 2002). They simulate different planning scenarios before launching a plan (HVOLBY; STEGER-JENSEN, 2010). Furthermore, APS systems can be configured for giving alerts to the appropriate organizational units when something out of the ordinary happens (WEZEL; DONK; GAALMAN, 2006).

3.2. APS systems structure

According to Neumann, Schwindt and Trautmann (2002), APS systems offer support at all planning levels along the supply chain while observing resources limitation. The APS system input data include size of order, order due date, available capacity, product type, process routine, process time, cycle time, setup time, yield, tact time, preventive maintenance, mean time to repair, mean time between failure, and Work In Process (WIP); whereas outputs include equipment loading, fab utilization, line utilization, order release time, and order start/finish time (CHEN et al., 2013).

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The main constituent modules of the APS systems in the three levels of supply chains are shown in Figure 1 (MEYR; WAGNER; ROHDE, 2005).

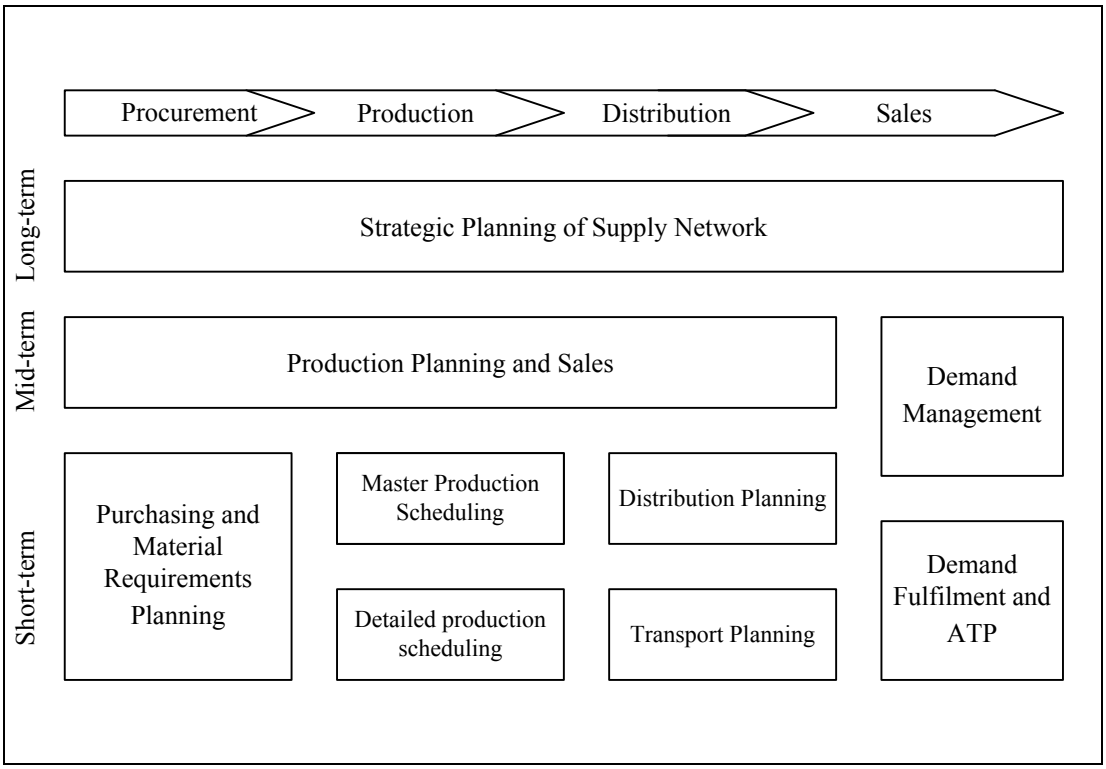

Figure 1: APS systems structure

The strategic planning of the supply network determines the structure of the supply chain in the planning horizon, including locations of factories and distribution centers and considers a long term planning horizon of ten years (GIACON; MESQUITA, 2011). The demand management balances customer requirements with the capabilities of the supply chain (CROXTON et al., 2002).

Production and sales planning aims at efficient use of company capabilities and the realization of the foreseen demands in the medium-term planning horizon, by planning simultaneously the functions of production, purchasing and distribution (STADLER, 2005). Master Production Scheduling (MPS) defines the end items quantity to be completed in each week of the short-term planning horizon, periodically updating the plans after collecting and recognizing the most recent

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information (OMAR; BENNELL, 2009). The MRP carries out the material requirements explosion through information from MPS, generating orders of assembly, manufacturing and purchasing, in order to meet the final products demand (OMAR; BENNELL, 2009).

Detailed production scheduling is generated taking into account the availability of capacity and materials, according to the guidelines of MPS (GIACON; MESQUITA, 2011). Distribution planning represents one of the most important activities in supply chain management and considers the availability of stocks and transports for generating the scheduling of deliveries (SAFAEI et al., 2010). Transport scheduling considers short-term factors, such as routing or vehicles availability (GIACON; MESQUITA, 2011). Available-To-Promise (ATP) aims to provide the customer specific requests in promised delivery date considering the demanded products availability (JUNG, 2012).

3.3. APS systems integration with other production planning and control systems

The production planning and control procedures used in the industry have always been subject to several changes. Many companies have recognized that the systems commonly used, represented by MRP II and ERP, do not support the planning in order to properly consider the capabilities of resources during the planning process (KRISTIANTO; AJMAL; HELO, 2011).

While APS systems themselves are an advance when compared to its predecessors, companies use a combination of systems for guiding the supply chain collaboration and planning (SETIA; SAMBAMURTHY; CLOSS, 2008). APS systems were developed under the combination of MRP with the Capacity Requirement Planning (CRP) for allowing the creation of suitable production plans and planning activities for the supply chain as a whole, providing procedures and methodologies that are able to react quickly to exceptions and variability (CHERN; YANG, 2011; KUNG; CHERN, 2009).

Traditional MRP systems do not sufficiently support the planner in settling production planning and control issues, and may create many problems on the shop floor for later production (CHEN; JI, 2007), such as often excess inventories, poor customer service, and insufficient capacity utilization (KANNEGIESSER; GÜNTHER,

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2011). According to Peng, Lu and Chen (2014), MRP systems generally make plans according to finite material requirements and infinite capacity requirements, meanwhile the production lead time which is actually depending on production planning is predetermined, whereas in APS systems plans are optimized within the boundaries of material and capacity constraints.

Using sales and inventory data from an MRPII system, it can produce a production plan in seconds or, at worst, a few minutes. APS systems can validate the plans generated by the MRP II system or can carry out planning, eliminating the need for such modules, being the use of MRP II directed toward the acquisition of product information, order and inventory (CHAMBERS, 1996).

APS does not substitute but it supplements existing ERP systems (STEGER-JENSEN et al., 2011). It is widely known that the strength of ERP systems is not in the area of planning. Thus, APS systems have been developed to fill this gap (STADTLER, 2005). According to Ou-Yang and Hon (2008), APS systems develop an appropriate production scheduling for supporting potential orders, while ERP systems are used for integrating the execution of orders related to business processes, and handling the basic activities and transactions, such as customer orders, accounting, finances, human resources, etc. (STEGER-JENSEN et al., 2011).

An APS system extracts information from the ERP database through input user interface, makes its calculations and sends the resulting plans back for distribution and execution. The APS sends to the ERP manufactured parts needs, purchase parts needs and projected orders completions, by using optimization techniques for modeling and determining the quantities. The ERP sends to the APS demands (customers' orders, forecasts, MPS, safety stock orders, transformer orders), item information, information of Bill Of Materials (BOM), operation information, resource information, resource group information, WIP status, finished and released jobs, scheduled jobs, run parameters, calendar, shifts and holidays. The schedule and utilization results can be saved in the database through the output interface (CHEN et al., 2013; GÜNTHER; MEYR, 2009; MUSSELMAN; O'REILLY; DUKET, 2002; RUDBERG; CEDERBORG, 2011).

3.4. APS systems capabilities

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The set of APS systems applications usually has the following capabilities: modeling capability, flow modeling, scheduling and optimization, planning capacities, constraints management and analysis, execution control (SETIA; SAMBAMURTHY; CLOSS, 2008).

The modeling capability defines the exact resources amount and constraints. Flow modeling creates routines based in product by product, configures workstations and alternative flows. Scheduling and optimization configure various jobs and process performance criteria based on operators available and resources constraints. Planning capacities plan resources and facilities for the long term through what-if analyzes. Constraints management and analysis identifies constraints in case of change in demand priorities. Execution control manages operations through intelligent ways of detailing reports.

In the shop floor the APS systems are responsible by following activities: order release, sequencing, dispatching and reporting (IVERT, 2012). The order release is related to the order release control, material availability check and generation of the shop packet. Sequencing is responsible by decisions that have to be made about which order will be processed next. Dispatching considerations are what information the dispatch list includes, how the shop floor gets information about any changes in the planned requirements, and what freedom the personnel have for setting priorities and to choosing the sequence. Information pertaining to the progress of orders on the shop floor and identification of possible problems are functions pertinent to the reporting.

3.5. APS systems implementation

From an APS system implementation perspective, the knowledge of APS and planning, experiences of the processes under investigation and implementation projects, and commitment to the project should be important individual factors (IVERT; JONSSON, 2011).

For Pacheco and Santoro (2001), the main deficiencies that may arise in the evaluation process of an APS system are poor assessment of the opportunities for improving the current system, deficient investigation of alternatives, and poor analysis of the relationship between adherence and quality of the solution. For overcoming these deficiencies, Pacheco and Cândido (2002) proposed the following

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actions: assessing opportunities for improvement and preliminary selection of alternatives, detailed analysis of adherence and quality of models solution, weighting of results obtained between models, analysis of commercial criteria and implementation strategy.

According to Pedroso and Côrrea (1996), for implementing programming systems with finite capacity (such as APS systems), are needed investments in software, hardware, training, implementation, system maintenance and organizational changes. Investments in software are related to the acquisition of the application itself, possible needs for this adaptation and its integration with other information systems of the company. In hardware, the equipment necessary for system management. In training, is related to the training of human resources for the management of new technology. In implementation, encompasses modeling and the availability of other necessary information. In system maintenance the values associated with the management of the system and the maintenance and upgrading of software and hardware. In organizational changes, necessary improvements for effective management of the system in the organization.

APS systems implementations comprise the following phases (IVERT; JONSSON, 2011):

1) The chartering phase: comprises decisions leading to funding an APS system. Typical activities comprise current state analysis, ideas of adopting the system, definition of key performance indicators, conducting business case for investment development, identifying project manager, approving a budget and schedule, and the selection of a software package.
2) The project phase: phase where activities are comprised in order to get the system up and running. Typical activities include model building, setup of internal data structures and databases, validation/testing, training, and go-live.
3) The shakedown phase: phase where organizations are coming to grips with the information system. Typical activities include cleaning up data and parameters, providing additional training to users, particularly on business processes, and working with vendors and consultants for resolving bugs in the software.

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4) The onward and upward phase: phase that continues from normal operation until the system has been replaced with an upgrade or a different system. Typical activities comprise post-implementation audit, continuous business improvement, technical upgrading, additional end-user skill building.

3.6. Benefits of the APS systems use

Table 1 lists the major benefits that can be obtained with the APS systems use, based on the results of the literature review.

Table 1: Key benefits of APS systems use

Benefits	Authors
More efficient management of supply chains	Boulaksil, Fransoo and Halm (2009); Brandenburg and Tölle (2009); Dayou, Pu and Ji (2009); Garcia-Sabater, Maheut and Garcia-Sabater (2012); Jonsson, Kjellsdotter and Rudberg (2007); Kristianto, Ajmal and Helo (2011); Kung and Chern (2009); Neumann, Schwindt and Trautmann (2002); Rudberg and Thulin (2009); Setia, Sambamurthy and Closs (2008); Zoryk-Schalla, Fransoo and De Kok (2004)
Higher throughput and shorter industrial lead time	Chen, Huang and Lai (2009); Dayou, Pu and Ji (2009); Lee, Jeong and Moon (2002)
Integration with ERP systems, other planning modules or process control systems	Arsovski, Arsovski and Mirovic (2009); Caputo, Gallo and Guizzi (2009); Chambers (1996); Chen et al. (2013); Garcia-Sabater, Maheut and Garcia-Sabater (2012); Giacon and Mesquita (2011); Hvolby and Steger-Jensen (2010); Jonsson, Kjellsdotter and Rudberg (2007); McKay and Wiers (2003); Ou-Yang and Hon (2008); Öztürk and Ornek (2014); Setia, Sambamurthy and Closs (2008); Steger-Jensen et al. (2011); Wiers (2002); Wiers (2009)
High processing speed	Chambers (1996); Giacon and Mesquita (2011)
Creation of suitable production plans	Chern and Yang (2011)
Consideration of capacity constraints and operating sequences	Arsovski, Arsovski and Mirovic (2009); Chen and Ji (2007); Hvolby and Steger-Jensen (2010); Neumann, Schwindt and Trautmann (2002); Peng, Lu and Chen (2014); Rudberg and Thulin (2009); Setia, Sambamurthy and Closs (2008); Zhong et al. (2013)
Increase in operational profits	Gen, Lin and Zhang (2009); Lee, Jeong and Moon (2002)
Reduction in inventory levels	Chen, Huang and Lai (2009); Lee, Jeong and Moon (2002); Villegas and Smith (2006)

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Quick reaction to exceptions and variabilities	Kung and Chern (2009)
Increased customer satisfaction	Steger-Jensen and Svensson (2004)
Support to the following S&OP process: forecast future demand, prepare preliminary delivery plan, prepare preliminary production plan, adjust and settle delivery plan and production plan.	Ivert and Jonsson (2010)
Jobs reprogramming	Setia, Sambamurthy and Closs (2008)
Evaluation of the profitability of different alternatives for meeting the customers' requests	Quante, Meyr and Fleischmann (2009)
Possibilities for graphical depiction of the resulting production schedules and quick access to additional information on the schedule elements	Brandenburg and Tölle (2009)
Manual modification of existing production schedules, especially for management by exceptions	Brandenburg and Tölle (2009)
Realistic and feasible delivery promises	Chen et al. (2013)
Facility of preventive maintenance scheduling	Chen et al. (2013)
Better allocation of workload, resulting in reduced overtime and outsourcing services	Chen et al. (2013)

4. CONCLUSIONS

This paper presented through a literature review key concepts, structure, brief description of its integration with other production planning and control systems, implementation process and key benefits of APS systems for companies.

In recent times, with the great transformations imposed by globalization, companies deal with increasingly demanding markets in relation to cost, schedule, quality, reliability and everything else that represents competitiveness. Their managers are constantly pressured to get progressive gains.

The lack of alignment among the various companies' productive resources can cause confusion in production schedules, which entails, among other problems, low productivity, low level of service and loss of customers, with negative impacts on your finances.

Many of the traditional production planning and control systems implemented in companies since the second half of the twentieth century have failures in the operation, because disregard capacity limits of production. APS systems represent a breakthrough for the production planning and control of companies, because consider the various constraints present in production processes.

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It is possible for companies, that with the use of APS systems, they achieve improvement in treatment to the delivery deadlines, fines and special freights reduction, raw materials, WIP and finished goods stocks reduction, production lead times reduction, better care of customer requests, improvement in productivity and overall efficiency of productive resources, purchases and hiring of outsourced services rationalization.

This paper did not intend to exhaust the issues raised here. His focus was directed to the conceptual analysis of the theme studied in papers found. In spite of possessing some limitations, this literature review aims to generate new knowledge and information through by rescuing of gaps that have already been addressed in previous researches (MARIANO; GUERRINI; REBELATTO, 2012). More detailed studies can be carried out and contribute to the development of this theme, because according to Gil (2008), exploratory researches constitute the first step of a broader investigation.

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