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Advanced planning and scheduling systems in manufacturing planning processes

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Abstract

An advanced planning and scheduling (APS) systems is defined as any computer program that uses advanced mathematical algorithms or logic to perform optimization, and/or simulation on finite capacity scheduling, sourcing, capital planning, resource planning, forecasting, demand planning and others. The expectations of APS systems have been high, both from academia and industry in the subject area of manufacturing planning and control. Relative the massive interest there has not been much written about how APS systems are used in practice and what effects an APS approach really results in. This thesis focuses on the use of APS systems in manufacturing planning and control (MPC) processes, and the research questions is to explore how APS can support these processes, which benefits that can be achieved and which prerequisites to consider when using APS systems. Three case studies have been conducted including seven case companies that use APS in different MPC processes. The results are presented in four appended papers. Empirical data from the case studies have mainly been conducted thorough interviews with actors involved in MPC processes.

The literature review and the case study analyses have generated frameworks describing how APS systems could support the activities in sales and operations planning (S&OP) and production activity control (PAC). A framework was also developed for when to use APS systems in S&OP processes. Three different types of benefits were identified when using APS systems in MPC processes; (1) decision support, (2) planning efficiency, and (3) learning effects. The prerequisites which may affect the probability of conversion success where separated into prerequisites identified in the selection phase, in the implementation phase, and in the post-implementation phase. Examples of prerequisites identified in the different phases were; the aim of the process, complexity in planning task, the design of the model, access to and quality of planning data, the capabilities of the APS system, the use of APS, user characteristics, planning organization, system support, system acceptance, and high discipline of users. The thesis has contributed with increased knowledge for the use of APS system in the MPC processes. In particular the definitions in the thesis, the identified variables, and the frameworks should be of interest for researcher, management, and consultants in the area of manufacturing planning and control.

Keywords: APS systems, manufacturing planning and control, benefits, prerequisites

List of included papers

This thesis is mainly based in the work contained in the following papers:

Paper I
Jonsson, P., Kjellsdotter, L., and Rudberg, M. (2007). ”Applying advanced planning systems for supply chain planning: Three Case Studies", *International Journal of Physical Distribution & Logistics Management,* Vol. 37, No. 10, pp. 816-834.

Paper II
Kjellsdotter-Ivert, L., and Jonsson, P. (2009). ”The potential benefits of advanced planning and scheduling system in the sales and operations process”. An earlier version of this paper was published in the proceedings of the Euroma conference in Groeningen, Netherlands, 2008.

(Submitted to *Industrial Management and Data Systems*)

Paper III
Kjellsdotter-Ivert, L., and Jonsson P. (2009), ” How to utilize advanced planning and scheduling systems in sales and operations planning”. An earlier version of this paper was published in the proceedings of the Euroma conference in Groeningen, Netherlands, 2008.

(Submitted to *Production Planning and Control*)

Paper IV
Kjellsdotter-Ivert, L. (2009), “Shop floor characteristics influencing the use of Advanced Planning and Scheduling systems”. An earlier version of this paper was published in the proceedings of the EurOMA conference, Göteborg, Sweden, 2009

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"Never say never". I always knew that engineering was not the subject or career for me. I was a typical sociologist. One who preferred history and arts subjects in favour of mathematics and physics. When I re-educated myself during the technical year at Chalmers University of Technology to get the qualifications of a science student, I was certain that I would not continue at Chalmers. In the middle of my studies at Industrial Economics at Chalmers, I knew for sure that I would definitely not become a PhD student. But here I am, writing the last lines on my licentiate thesis of engineering. And I know one thing for sure; I never would have been here without the help from a large number of people.

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Göteborg, November, 2009
Linea Kjellsdotter Ivert

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1 Introduction

This thesis deals with the use of advanced planning and scheduling (APS) systems in manufacturing planning and control (MPC) processes. The introduction chapter presents the background and problem area, the overall aim, the scope of the thesis, and definitions. An outline of the thesis is presented at the end.

1.1 Background

"Plans are nothing; planning is everything" (Dwight D. Eisenhower, 1890 - 1969)

Effective planning and control of material flows and production processes are usually seen as a key to success of a manufacturing company (Vollmann et al, 2005). During the latest 50 years, both academia and industry have put great effort into developing and designing successful approaches and methods for manufacturing planning and control (Gayialias and Tatiopolous, 2004). Indeed, the methods and approaches of how to plan and control production and material change over time. This occurs in line with changes in customer requirements, and environment and technology improvements (Vollmann et al, 2005). Until the 1950s, most companies applied a made to order strategy because acceptable delivery times were long and production was based on custom orders. The planning situation required relatively simple methods and planning tools. In the 1950s the conditions changed and access to new supporting tools was required. New planning methods, developed by practical men, arose and books were written and published on the subject. It was during this period that computers were introduced into manufacturing companies in order to support planning tasks (Jonsson and Mattsson, 2009).

Computer based information systems (IS) in manufacturing planning and control, have since their introduction evolved to cope with the needs of manufacturing firms. It is possible to identify a route of evolution starting with the introduction of manufacturing requirement planning (MRP) systems in the 1960s. Through the manufacturing resource planning (MRPII) systems in the 1980s and on through enterprise resource planning (ERP) systems in the 1990s ending in recent supply chain management (SCM) software such as advanced planning and scheduling (APS) systems (Brun et al, 2005). APS systems are either add-ons or direct integral components of ERP systems which create the support mechanism for planning and decision making at the strategic, tactical and operational planning levels (Kreipl and Dickersbach, 2008). In general, APS systems are said to create better plans than its predecessors as they include advanced functionality such as optimization and simulation (Chambers, 1996; Bendoly et al, 2004, Hadaya, 2008). It is many times argued that APS systems are especially well-suited for environments where simple planning methods cannot adequately address complex trade-offs between competing priorities

(Jonsson et al, 2007; Rudberg and Thulin, 2009). Vieria and Faveretto (2006) propose advanced algorithms in computer system to deal with complicated planning questions such as: What is the most adequate resource to use when more than one can be picked? What is the best assignment of product quantities to resource so that changeover can be minimal? What if some products could only be scheduled after others? What if the lines have different processing rates? What if some products cannot be scheduled simultaneously because they have the same tools, pallets, or fixtures? In a study made by Michel (2007) it was found that companies valued advanced functionalities such as what-if analysis tools and real time dashboards in their midterm planning as different departments need to reach consensus concerning the creation of production and delivery plans.

The expectations of APS systems have been high from both academia and industry active in the area manufacturing planning and control. Turbide (1998) for example stresses that "*APS systems represent the most relevant innovation in the world of manufacturing since the introduction of MRP systems*", and Bermudez (1999) concludes that "*APS systems are a superb example of innovative software developers using advanced technologies to respond to the requirement of a new business paradigm*". Gayialias and Tatiopolous (2004) argue that "*APS systems have shown that operations research algorithms can be applied in practice…*" Furthermore, studies indicate that implementation of APS functionalities is top priority in industry (Straube, 2006) and many companies have started to invest in APS modules (Stadtler and Kilger, 2005).

Investing in APS systems is expensive and time consuming and it is important that the investment generates a profit. For a considerable time there has been much discussion on the value of IS support in planning and controlling material flows and production (Renkema, 1998; Zhu and Kreamer, 2005). The "IS/IT value paradox" i.e. the gap between substantial firm spending on IS/IT and the widespread perception about the lack of value, has been discussed in articles, magazines and journals and at conferences and seminaries, all around the world (Lin and Pervan, 2003; Chau et al, 2007). IS/IT managers have found it increasingly difficult to justify rising IT/IS expenditures and are often under immense pressure to find reliable ways to ensure that expected benefits from the IS/IT investments are realized (Lin and Pervan, 2003). An APS system is no exception, therefore; everyone is not convinced that APS systems are "the solution" to outstanding planning and control of material flows and production. People say that Western industry has taken the wrong path, and the use of so many complex methods and planning systems – which cannot be made to work properly anyhow- should be abandoned (Jonsson and Mattsson, 2009). Research also suggests that several APS systems implementations failed or did not meet the initial expectations (McKay and Wiers, 2003; Stadtler and Kilger, 2005).

In relation to the massive interest in and the high expectations of APS systems from industry and academia in the subject area of manufacturing planning and control, there has not been much written about how APS systems are used in practice (Wiers, 2009; Rudberg and Thulin, 2009) and what effects an APS approach results in (Hendericks et al, 2007). Instead, most research concerning APS systems has focused on designing advanced algorithms to solve planning and scheduling problems (Lin et al, 2007). One reason for the gap between APS theory and practice may be that research in manufacturing planning and control implicitly assumes that IS functionality follows the requirement as specified in models (Wiers, 2002). This assumption is usually correct in cases where software is custom built for a specific situation. However, in reality, companies implement commercially available APS systems. Consequently, the understanding of when and how to use APS systems in order to obtain benefits, is limited. For practitioners, the potential value of knowing why, when and how to successfully use APS systems and which benefits to expect is obvious. Senior executives ought to use this knowledge in the selection, implementation and post-implementation phase to increase the success rate, and as an evaluation mechanism, to access whether anticipated benefits are realized. For academia in manufacturing planning and control, it is important to understand weather the APS dominant approach really solves the real-world planning and scheduling problems considering the vast volumes of mathematical models and algorithms developed during the years (Lin et al, 2007). It is also interesting, for researcher in manufacturing planning and control and IS, to understand how benefits are created when using APS systems. It can be argued that as APS systems are a natural extension to MRP, MRPII and ERP systems (Setia et al, 2008) the literature in these latter domains can be used to better understand the value-creation of APS systems. Still, different impacting measures are appropriate for different types of systems (DeLone and McLean, 2003) and there is a need to find out how to access benefits of APS investments.

1.2 Overall aim

The overall aim of this thesis is to study the use of APS systems in manufacturing planning and control processes.

This is a very broad aim and in the forth section of chapter 2 more precise research questions are formulated as the frame of references is needed to define these questions. Detailed purposes are given in each appended paper. Still to give some understanding of what one could expect of the following sections it could be said that the word “use” deal with “why”, “when”, and “how” to use APS systems in different planning processes.

1.3 Scope

Manufacturing planning and control is a large research area involving many aspects and variables on different planning levels. The main focus of this study is on the sales and operations planning (S&OP) process, and the production activity and control (PAC) process as illustrated in Figure 1. The reasoning behind this is that APS systems foremost are used in the PAC process (Wiers, 2009) but the potentials are expected to be higher in the S&OP process as more advanced functionalities are available in the APS modules supporting planning processes at a higher planning level. Still the master production scheduling, the rough cut capacity planning in the master production scheduling, the material planning and capacity requirement planning in the order planning, and the forecasting and customer order in Figure 1 will be touched upon.

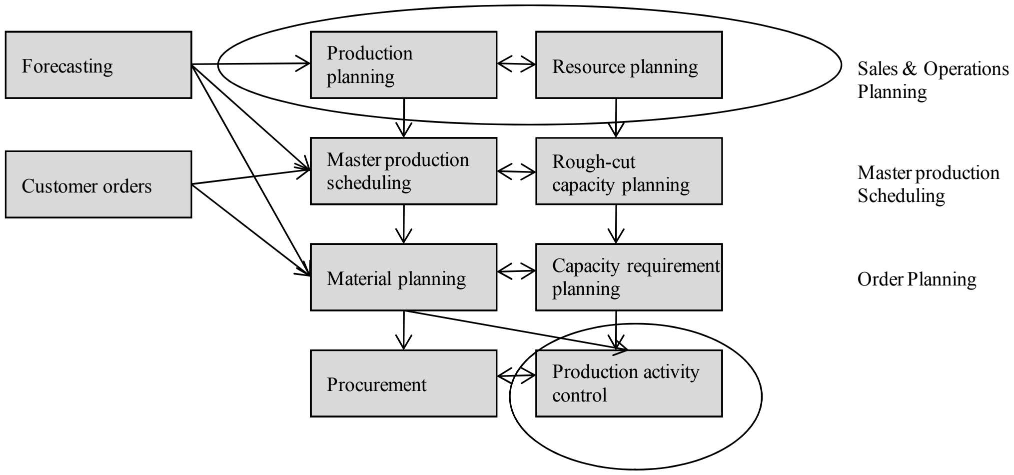

Figure 1: The scope is sales and operations planning and production activity control in the manufacturing planning and control system (The manufacturing planning and control structure is based on Jonsson and Mattsson, 2009)

Commercial, off-the-shelf APS systems involve a number of software modules supporting planning tasks at different planning levels (i.e.: strategic, tactical, operational) and in different supply chain processes (i.e.: procurement, production, distribution, sales). Stadtler and Kilger (2005) propose a common structure presented in Figure 2 in which the different APS modules are mapped against the planning horizon (at the y-axes) and the supply chain process (at the x-axes). In this thesis the focus is on the multi- site master planning module, the demand planning module, and the production scheduling module (Figure 2). The reason for why these modules are the focus is that these are the modules that support the sales and operation planning, and the production activity control processes.

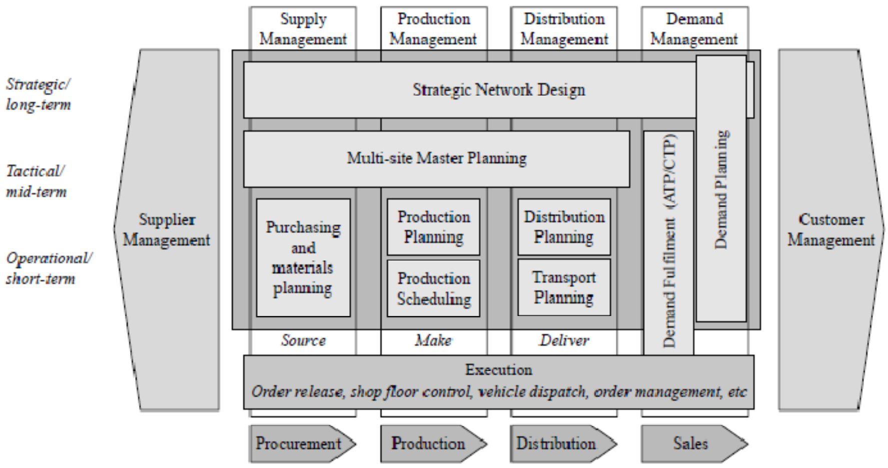

Figure 2: The focus is on the multi-site master planning module, the demand planning module and the production scheduling module. The matrix is based on Stadtler and Kilger (2005).

1.4 Definitions

APS – There are many definitions of an APS system. The APICS definition covers both commercial, off-the-shelf software and bespoken software as well as a system supporting decision at all planning levels or only at operational planning levels. This is the definition that is most widely used in research papers. It is also the definition that will be used in this thesis. Still, the APICS definition of APS systems is very broad and it is not easy to understand what different functionalities are included in an APS system. As it is more or less impossible to take one step further in detailed level and still keeping the wide range of what constitutes an APS system this thesis focuses on each unique software module under investigation. In other words, in this thesis an APS system is defined as "*any computer program that uses advanced mathematical algorithms or logic to perform optimization and/or simulation on finite capacity scheduling, sourcing, capital planning, resource planning, forecasting, demand management, and others. These techniques simultaneously consider a range of constraints and business rules to provide real-time planning and scheduling, decision support, available-to-promise, and capable-to-promise capabilities. APS often generates and evaluates multiple scenarios"* (APICS, 2007). In order to better understand the functionalities of APS systems one must study each unique software module. In this thesis the software modules of interest are the demand planning module, the multi-site master planning module and the production scheduling module. The functionalities are described in section 2.1.2.

ERP – Enterprise Resource Planning (ERP) systems are integrated enterprise-wide standard IS which automate all aspects of an organization's business processes. The idea of the ERP system is to implement a single system by using one database which contains all data for software modules such as; manufacturing, distribution, finance, human resources, purchasing, warehouse management, and project management (Berechet and Habchi, 2005). As a planning system, the ERP system has been criticised for having many limitations (e.g. Hamilton, 2002; David et al, 2006).

MRP- Material Requirement Planning (MRP) is a material planning method that uses a production bill-of-material and a master production schedule to determine material needs and replenishment timing (Moon and Phatak, 2005, Aghazadeh, 2003).

MRP II- Material Resource planning (MPRII) is usually said to be a development of MRP, where the development lies in the capability to integrate other resources than the materials (Mattsson, 2004). Planning in accordance with the concept illustrated in Figure I is sometimes called MRP II (Jonsson and Mattsson, 2009)

IS- Information System (IS) is a system that uses information technology to capture, transmit, store, retrieve, manipulate, or display information. One way to categorize IS is by application by, for example, administration system, manufacturing systems, planning systems, or/and accounting systems. Another way to categorize IS in what they do, for example on-line systems, decision based systems, and knowledge based systems. (Stefansson, 1999)

IT- Information Technology (IT) is the hardware and software that makes information systems possible. The term hardware includes the devices and other physical things involved in processing information, such as computers, workstations, physical networks, and data storage and transmitting devices. The software is the computer program that interprets the user inputs and tells the hardware what to do. (Stefansson, 1999)

1.5 Thesis outline

Chapter 1 (Introduction) presents the background and the problem area of APS systems in manufacturing planning and control processes. The overall aim of the thesis is presented, the scope of the study is discussed, and definitions to some concepts used in the thesis are given.

Chapter 2 (Frame of references) reviews previous research on APS systems, the manufacturing planning and control processes and the IS value creation. It also lays the foundation of the theory used in the analysis. The section ends by generating detailed research questions.

Chapter 3 (Methodology) presents the methodology used in the research.

Chapter 4 (Summary and results of appended papers) summaries the four appended papers in the thesis and presents the results and the theoretical and practical contributions from each paper.

Chapter 5 (Discussion) discusses the results of the thesis. The chapter sets out to answer the research questions presented in Chapter 2. All research questions are directly or indirectly analyzed in the papers. The theoretical and practical contributions are summarized.

Chapter 6 (Conclusions and further research) presents the conclusions and gives suggestions for further research.

2 Frame of references

There are two goals with the frame of references; the first is to review previous literature and to identify possible gaps. The second is to lay the foundation for the theory used in the analysis. In the first section the definition of APS systems is discussed. The second section introduces the manufacturing planning and control system. In particular, the S&OP process and the PAC process are described and discussed. In the third section, literary findings on IS are presented in order to generate some general models and findings for how value is created and which benefits are expected when using IS in the manufacturing planning and control processes. In the fourth section the research questions are presented based on the frame of references. These research questions are not generated from separate parts of the frame of references; rather they are a combination of different parts.

2.1 Advanced planning and scheduling systems

"An APS is a system that suits like an umbrella over the entire chain, thus enabling it to extract real-time information from the chain, with which to calculate a feasible schedule, resulting in a fast, reliable response to the customer" (van Eck, 2003).

"An APS system is any computer program that uses advanced mathematical algorithms or logic to perform optimization or simulation on finite capacity scheduling, sourcing, capital planning, resource planning, forecasting, demand management, and others. These techniques simultaneously consider a range of constraints and business rules to provide real-time planning and scheduling, decision support, available-to-promise, and capable-to-promise capabilities. APS often generates and evaluates multiple scenarios" (APICS, 2007)

"An APS system is a software system designed to integrate with ERP and MRP systems to enhance the short term production planning and scheduling" (Bitepipe, 2009)

As the above stated quotations indicate there are many varying opinions regarding the definition of APS systems. It can refer both to commercial, off-the-shelf software and to bespoke software based on mathematical models solving a specific planning problem. It can refer to a system supporting decisions at all planning levels or a system only supporting the decisions at one particular planning level. One explanation for this is that APS systems originates from different fields; it can be defined as an extension of ERP systems but it also stems from in-house developed decision support systems (DSS) (De Kok and Graves, 2003). Besides, APS systems are a relatively young technology that has only recently gained a lot of attention, which means that the term is not settled. The term APS systems were introduced first in the 1990s (Moon et al, 2004). Another explanation for the ambiguousness concerning APS systems is that software vendors call their solution APS but the functionality in the solution differs between different vendors (Hamilton, 2002). Leading APS vendors i2, Aspen Technology and JDA (Helo and Szekely, 2005; van Hezewijk et al, 2007; Kreipl and Dickersbach, 2008) support planning processes at all planning levels in the SCM matrix (Figure 2) whereas other software vendors such as OM Partners and Quintiq emphasize production planning and detailed scheduling functionalities (van Hezewijk et al, 2007). Besides, the distinction between APS systems and other systems, for example ERP systems, is somewhat blurry and it is not easy to determine which modules and functionality that belong to which system (Helo and Szekely, 2005). Most leading ERP vendors such as SAP and Oracle have for instance an advanced planning solution that is included in their ERP suite. Others terms are also used to describe the same thing, for example advanced planning and optimization (APO), advanced planning systems (APS) and supply chain planning (SCP) (Chen, 2001).

2.1.1 The APS functionalities

So what is an APS system? Is it possible to find any "typical" APS functionalities? Usually the functionalities of the APS systems are viewed in the light of well-known deficiencies of its predecessors. Hamilton (2002) for example compares APS logic with traditional MRP logic. The major difference between APS logic and MRP logic is, according to Hamilton (2002), that the former uses a finite scheduling based on capacity and material constraints to synchronize activities in the supply chain. Whereas the latter uses a backward infinite schedule to explore demands to make items through the bills and generate a production schedule. Van Eck (2002) compares APS systems with MRP/II and ERP systems (see Tables 1 and 2).

Other researchers have tried to describe an APS system by identifying typical APS characteristics. Stadtler and Kilger (2005) have for example identified three main characteristics of APS systems; (1) integral planning of the entire supply chain, at least from the suppliers up to the customers of a single enterprise, or even of a more comprehensive network of enterprises, (2) true optimization by properly defining alternatives, objectives, and constraints for the various planning problems and by using optimization planning methods; either exact ones or heuristics and (3) a hierarchical planning system which is the only framework permitting the combination of the two preceding properties. Helo and Szekely (2005) identify five main functionalities of APS systems; (1) supply chain inventory and lot size optimization, (2) available-to-promise/capable-to-promise calculations, (3) inventory and transportation optimization; order decoupling point definition, (4) reduced inventory points and (5) material flow analysis. Wiers (2009) identifies three elements of APS systems; (1) it is based on a model of the system to be planned or scheduled, (2) it contains supporting or automating functionalities to generate plans or schedules and (3) it provides a graphical user interface to present the plan or schedule to the user and to give the user the option to manipulate the plan or the schedule. Setia et al (2008) consider an APS system suite to include the following capabilities; capacity modeling, route modeling, scheduling and optimization, planning capabilities, constraint management and analysis and execution control (see Table 3).

Table 1 Comparison APS systems and MRP/II systems (Adopted from Van Eck, 2002).

APS system	**MRP/II system**
Customer preference may be varied depending on the business importance of the customer	All customers are given equal preference in the system
Lead times can be dynamically entered by contacting the customers	Lead times are fixed and known a priori
APS applications dynamically calculate a plan and schedule within minutes of any change being made to them	MRP runs are usually batch time and have longer duration times
Support superior decision making by what-if analysis and simulations	Does not support any decision making aids
Smart and easy to drill down reporting based on the identification of exceptional conditions	Detailed reports, which are hard to read and decipher
Material allocation according to availability and according to the criterion specified	Material allocation done on a first come first service basis

Table 2: Comparison of APS systems and ERP systems (Adopted from Van Eck, 2002)

APS system	**ERP system**
Facilitate real time analysis for planning, scheduling and optimization decision	Level of detail is coarser and the technology does not support real time analysis and simulation to aid dynamic decision making
Material and capacity constraints are evaluated together to arrive at an optimal decision	No consideration for interdependency of material and capacity availability
Multi-plant planning is supported	Multi-plant planning not supported at the same time
Lead times can be calculated dynamically	Lead times are assigned statistically and manually
Production schedules can be optimized to increase throughput	Absence of optimization capability for production schedules
Results can be entered into the system to prove the processes and data	Results can be entered into the system to improve the process and data

Table 3: Application capabilities and solution details of APS systems. The name of application suite is followed by the name of vendor, offering the application in parenthesis (Adopted from Setia et al, 2008).

APS capabilities	Description	Example Application and Solutions
Capacity modelling	Exact definition of resources and constraints	
Route modelling	Create routing on a product-by-product basis, set up alternate workstations and operations workflows that help tie workstations together and split operations in to separated tasks, and place limitations or special setup on operations	Demand planning module, supply chain planner, supply chain strategic, factory planner, transportation modeling and analysis (i2 Technologies)
Scheduling and optimization	Schedule and optimize various jobs and process performance criterion based on available operators and resource constraints	
Planning capabilities	Plan resource and facilities for the long term, through what-if analysis support the available to promise quantities improve processes and discover production constraints, and allocate resource to specific tasks	Demand planning, supply management, network design and optimization (JDA)
Constraint management and analysis	Identify constraints and reschedule operators, and resources in case of change in priorities of demand	Production planning and detailed scheduling, global available to promise (SAP)
Execution control	Manage the operations by exceptions and through smart easy to drill down reporting	

It is difficult to define APS thorough comparing it with its procedures as it would probably only make the understanding of APS more muddles. As seen from the discussion above many ERP systems include APS functionalities and it will be an impossible task to draw the line between the different systems. Besides, the evolution has not stopped and tomorrow´s APS systems probably include other functionalities than are not included today. Another suggestion would therefore be to try to define APS through its functionalities. But also this is a difficult task as there are many different modules included in an APS suite and these modules have different functionalities. This being so the author's opinion is that it is more appropriate to understand the functionalities of each module and in the upcoming sections the APS modules will be described.

2.1.2 The APS modules

Stadtler and Kilger (2005) introduced the basic concept and architecture of commercial APS systems in 2000. According to Stadtler and Kilger (2005) the following software modules are normally included in commercial off-the-shelf APS systems; demand planning, strategic network planning, multi-site production planning, purchasing and material requirement planning, production planning, production scheduling, distribution planning, transport planning and demand fulfillment [1] (see Figure 2). Since this thesis focuses on the demand planning module, we describe the multi-site production planning module and the production scheduling module in detail below.

The demand planning module is used to support market demand forecasting by using different forecasting methods. A common feature of APS demand planning tools is the possibility to integrate different departments/companies into the forecasting process, and to aggregate/disaggregate forecasts according to pyramid forecasting (Kreipl and Dickersbach, 2008).

The multi-site master planning module aims at synchronizing the flow of materials along the supply chain, thereby balancing demand and capacity. It supports the mid-term decisions concerning efficient utilization of production, distribution and supply capabilities (Stadtler and Kilger, 2005). The multi-site master planning module not only balances demands with available capacities but also assigns demands (production and distribution amounts) to sites in order to avoid bottlenecks, wherefore it has to cover one full seasonal cycle, or at least 12 months in terms of weekly or monthly time buckets. Owning to the complexity and detail required in the model, only constrained (or near-constrained) resources are modeled in detail. To increase the solvability of the model, most vendors distinguish between hard and soft constraints in the linear programming (LP) or mixed integer programming (MIP) model that is used (Entrup, 2005). While hard constraints have to be fulfilled, the violation of soft constraints only renders a penalty in the objective function.

The production scheduling module aims at generating feasible production schedules (dispatch list) for the shop floor over a relatively short interval of time considering all modeled constraints and objectives (Hamilton, 2003). The production scheduling module produces a production schedule of operations for each work center in the sequence in which operations are expected to be carried out where available capacity is considered (Jonsson and Mattsson, 2009). The production scheduling module are designed to cover all classes of scheduling problems (for example single machine problems, parallel machine problems, flow shop problems, job shop problems, open shop problems) (Kreipl and Dickersbach, 2008). Common scheduling heuristics in the production scheduling module are versions of genetic algorithms and constraint-based programming since optimization algorithms cannot calculate the actual optimum within acceptable timeframes (Stadtler and Kilger, 2005). For the same reasons as for the multi-site master planning module, only a subset of all existing resources on the shop floor – those which may turn into bottlenecks – will have to be modeled explicitly. The production schedule can be generated at a two-level planning hierarchy or in one step (Stadtler and Kilger, 2005). In a two-level hierarchy the step for production planning and production scheduling are separated (as in Figure 2) whereas in a single planning level they are combined. The main difference between production planning and production scheduling algorithms is, according to Kreipl and Dickersbach (2008), the fact that production planning algorithm creates, changes (date and quantity), or deletes planned orders in order

[1] Note that the number of modules and the names of the modules in APS systems vary from different software suppliers. Still the planning tasks supported are basically the same.

to match a given demand and supply situation at the factory. Production scheduling algorithms on the other hand change the start and finish date and, if possible, the resource of the planned production orders and their operations, but not the quantity

2.2 The manufacturing planning and control processes

In practice many companies plan and control their material and production flows in a hierarchical structure with different time horizon and detailed information. One hierarchical planning structure commonly used is the Manufacturing planning and control (MPC) system (Olhager et al, 2001; Vollmann et al, 2005). The MPC planning processes hierarchy originates from the Association of Operation Management (APICS) where sales and operations planning (S&OP) has the longest planning horizon and the smallest level of detail. It balances the sales/marketing plans with available production resources and results in an agreed-on company game plan that determines the manufacturing role in meeting company strategy. Next follows the master production scheduling (MPS). It is the disaggregated version of the S&OP. Resource planning determines the capacity necessary to produce the required products now and in the future (Vollmann et al, 2005). There are many similarities between S&OP and MPS and in many companies these both planning levels are integrated into one planning process (Jonsson and Mattsson, 2009). Next in the hierarchy comes the order planning which could be seen as the function within a company that executes plans established at the strategic and tactical level at the company (ibid). The last process in the MPC system is the production activity control (PAC) with the shortest planning horizon and the largest level of detail. It concerns the execution of detailed material plans and describes the planning and release of individual orders, and when necessary detailed scheduling and control of individual jobs at work centers (Vollmann et al, 2005). Planning in accordance with the MPC system is sometimes called manufacturing resource planning (MRPII). As the main focus in the thesis is S&OP and PAC these processes will be described below.

2.2.1 Sales and operation planning

Sales and operations planning (S&OP) as a terminology was originally founded in the articles concerning MRPII or similar systems, where some authors used it interchangeably to refer to the term aggregated production planning (Ling and Goddard, 1988; Olhager, 2001; Feng et al, 2008). Considering the fact that S&OP have existed as a principle for at least 25 years, relatively little has been published until recently. Some say that the recognition is on the rise (Feng et al, 2008) and that S&OP will increase in importance as its complexity and the rate of change increases across the industry (Wallace, 2006). Others suggest that companies are moving away from S&OP as they have experienced that it does not live up to the expectations (Lapide, 2005). Until recently, research on S&OP has focused on its definition, processes, activities, implementation procedures, and case studies addressing the benefits after its implementation (Feng et al, 2008).

According to the dictionary of APICS (2000) the definition of S&OP is *"…setting the overall level of manufacturing output and other activities to best satisfy the current planned levels of sales…while meeting general business objectivities of profitability, productivity etc, as expressed in the overall* *business plan"*. Just as the definition implies, S&OP sets the frame for the decisions at the lower levels, based on the business plans, business goals and future visions (Proud, 1994 and Ling and Goddard, 1988). It is the main link between the top management and the subordinated plans. According to Stadtler and Kilger (2005) decisions taken at this level are of the greatest impact on profitability and competitiveness. S&OP seeks to align various functions in the company and is sometimes seen as a tool that helps the managing team towards collective decision making (Wallace, 2006). Typically the S&OP is made on an "aggregated" or "family" level and covers a sufficient span of time to make sure that necessary resources are available (Ling and Goddard, 1988). Roughly, S&OP can be divided into a sales plan (based on forecasted demand) and a production plan, which determines the capacity requirements, inventory level and/or backlog level (Ling et Goddard, 1988; Wallace, 2004). The capacity planning at the S&OP level concerns the evaluation of capacity requirement, decisions about future capacity adjustments, and the problem with having sufficient capacity is of a financial nature (Jonsson and Mattsson, 2009). There are two basic strategies used to develop a production plan at the S&OP level; chase and level (Olhager and Selldin, 2007). A chase strategy means that production is changed to match demand, whereas a level strategy produces an amount equal to the average demand (APICS, 2000). In many cases it is not possible (nor desirable) to maintain a pure S&OP planning strategy. Instead, a middle way with the aim of finding an efficient trade-off between the pure strategies is applied (Olhager et al, 2001). When managed in an appropriate way the S&OP process is supposed to generate many benefits to the company in the form of improved customer service, reduced inventory levels, shorted customer lead times, stabilized production rates, better work with suppliers, improved teamwork between sales, operations, finance and product development, as well as possibilities to react to new business opportunities (Wallace, 2004; Vollmann et al, 2005; Bower, 2006).

S&OP typically follows a five-step process; 1) Forecasting future demand, 2) Preparing a preliminary delivery plan and setting up goals for inventory or customer order backlog, 3), Preparing a preliminary production plan, 4) Adjusting the delivery plan and production plan and 5) Settle the delivery plan and production plan (Wallace, 2004; Grimson and Pyke, 2007; Jonsson and Mattsson, 2009). How often the S&OP process is conducted varies from case to case. It also depends on the type of business, current delivery lead times, how rapidly the market changes and the frequency of product renewal. Another factor to take into consideration when conducting the S&OP process is how often it is necessary to check off different operations with their budgets and to make new budget forecasts. In most cases, sales and operations planning processes are carried out monthly but can also be carried out more frequently (Grimson and Pyke, 2007).

According to Grimson and Pyke (2007), software systems may be required in the S&OP process, but not too early in the implementation process. The reason is that it is more important to have a well understood S&OP business process than it is to have elegant software. Grimson and Pyke (2007) further propose an S&OP integration framework to categorize the maturity level of different S&OP processes. The framework uses a one to five ranking across five dimensions;

meetings and collaboration, organization, measurement, information technology, and S&OP plan integration. A Stage 1 company does not have any S&OP process, whereas Stage 5 relates to a company with a proactive S&OP process characterized by event -driven meetings, real-time access to external data, seamless integration of plans, and profit -focused processes. A Stage 5 the company is also a company where S&OP is understood to be a tool for optimization. Operations optimization software, such as finite scheduling and real time integrated solutions with S&OP workbench for sharing information about sales and operations plans among team members, are most likely required to achieve a Stage 5 S&OP process (ibid). Genin et al (2007), emphasize the great potential of APS systems as a support for the S&OP process since its capabilities of frequent rescheduling leads to several changes in the S&OP decisions, thus reducing the stability necessary for the plans at the operational level and throughout the supply chain. Michel (2007), stresses that it is important to use decision support in the S&OP process because it is difficult to reach consensus among the different departments and during meetings. The software most valued by the companies included in the study of Michel (2007) for supporting the S&OP process were: "what-if" analysis tools, real time S&OP dashboards and demand planning (Michel, 2007).

2.2.2 Production activity control

Production activity control (PAC), or shop floor control, concerns execution of material plans (Vollmann, 2005) and is said to have three main purposes (Arnold, 1998); (1) To release orders at the rate that capacity conditions will allow them to be executed with reasonable throughput times, (2) To ensure that start-up materials are available when each order is planned to start, and (3) To ensure that orders released for manufacturing in the workshop are completed in a suitable sequence with respect to delivery precision and throughput times.

The PAC process consists of a number of activities presented in Figure 1. The relative importance of these activities will to a large extent depend on the manufacturing processes at the company (Arnold, 1998). The primary differences are between a product line and a job shop process (Jonsson and Mattsson, 2009). In a product line the control of order release and priority control takes place almost simultaneously. In a job shop, on the other hand, all activities in PAC are roughly equal in importance and scope. In general the following applies: First the upper planning levels initiate a manufacturing order; the order normally contains information on start time, due date and quantities. Before the order is released to the workshop there must be capacity available to carry it out (order release control), material necessary for its manufacture must be available (material available check) and information required for executing the manufacturing order must be communicated to the workshop (generating a shop package). When the order is released to the workshop, its operations must be executed in an appropriate sequence. This activity is called sequencing (Stoop and Wiers, 1996) or priority control (Jonsson and Mattsson, 2009). The execution of the operations in the workshop is often referred to as dispatching (Stoop and Wiers, 1996). Finally, the fact that manufacturing orders and operations have start and finish times does not mean that they necessarily will be started or completed at the times stated. Thus, information pertaining to the progress of orders in the workshop should be reported to the higher planning levels so that they can be aware of what is happening as well as intervene in order to correct possible problems. There are three different levels involving job reporting: to report the entire order, to report the operations and to report materials withdrawn for the order or delivered when the order has been completed (Jonsson and Mattsson, 2009).

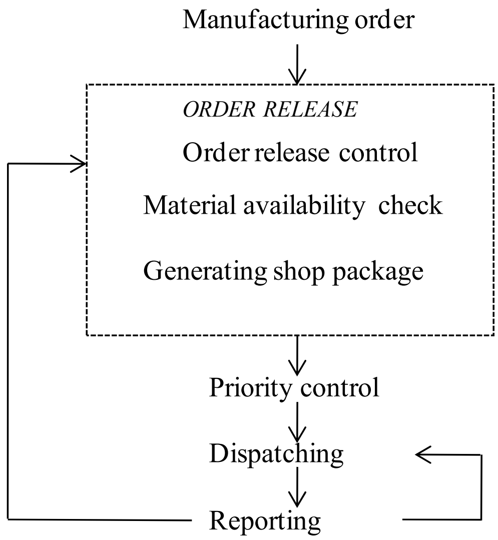

Figure 3: The main components in PAC (Based on Jonsson and Mattsson, 2009)

The majority of the manufacturing companies today use MRP logic in ERP systems to plan material requirements and release manufacturing and purchasing orders (Jonsson and Mattsson, 2006). Nevertheless, there are several methods to ensure that the released orders to the workshop are executed in an appropriate sequence. Some companies pass the list of released orders to the supervisors or foremen, who in turn make local scheduling decisions supported by experiences or simple priority rules. Others make use of more or less sophisticated scheduling algorithms in computer systems. As humans are not well equipped to control or optimize large and complex systems, practitioners in manufacturing planning and control are often convinced that much can be improved regarding manual scheduling (Kostas et al, 2003). The academic field in manufacturing planning and control has for decades formulated various scheduling techniques in an attempt to render feasible production scheduling. Production scheduling problems are mostly categorized as single machine problems, flow shop problems, and job shop problems (Kreipl and Dickersbach, 2008). Different objective functions and additional criteria like priorities, sequent depended set-up times or parallel resources lead to a huge number of scheduling problem classes. For each class of scheduling problems, simple priority rules, and also sophisticated scheduling algorithms have been developed (ibid).

2.3 Value creation in information systems

A large amount of literature has been conducted in different fields, for example management information system (Ives et al, 1980), information system (DeLone and McLean, 1992), decision sciences (Guimaraes et al, 1992) and production economics (Zhang et al, 2005), with the aim of identifying benefits of IS and its causes as well as explaining the relationship between benefits and its causes. In general, the results of the studies have been mixed both when it comes to identifying the benefits (Mirani and Lederer, 1988), and to find out which factors that cause the benefits (Grover et al, 1996) and the relationship between benefits and its causes (DeLone and McLean, 2003). The reasons for this are many; benefits can mean different things to different people and be captured at different units of analysis (Miriani and Lederer, 1988). It is also difficult to isolate the contribution of the information system functions from other contributors to their performance (Chau et al, 2007). Besides, the opinions regarding what variable that may cause success and what variable which is part of the success have been divided (Zhang et al, 2005). Yet, another explanation for why the results are divided when it comes to identifying IS benefits and its causes, is that the domain of focus has been different in different studies. Some studies have focused on identifying and explaining benefits and causes of a particular system, whereas other studies have tried to make more generalized conclusions by lumping together all kinds of systems under the information systems umbrella (Grover e al, 1992). As there has been relatively little written about which benefits to expect from APS systems and how to obtain APS benefits, previous literature concerning MRP/II, ERP and decision support systems (DSS) has been scanned. This section will present the IS benefits and prerequisite for achieving IS benefits.

2.3.1 Information system benefits

This section will give some example of IS benefits identified in the previous literature (Table 4). The literature will be described in a chronological order and the domains cover both unique systems such as MRP, DSS and SCM software as well as IS as a whole.

Schroeder et al (1981) measures MRP system benefits in a survey of users in two ways; tangible measures of manufacturing performance and subjective benefits. The tangible performance measures were selected based on the types of measures usually used by companies to reflect performance. It consisted of the following; percent of delivery promises met, inventory turnover, delivery lead time, percent of split orders and number of expeditors. The subjective benefits consisted of; improved competitive position, improved customer satisfaction, better production scheduling, improved plant efficiency, reduced safety stocks, better cost estimation, better control of inventory, improved coordination between divisions and improved morale in production.

Money et al (1988) advocate a methodology for identifying intangible benefits for a specific DSS, quantifying these in value terms and establishing a decision rule for identifying the significance of proposed systems. They created a list of perceived DSS benefits using their methodology: operational benefits (clearly time and labor savings, improved timelines, smoother administration), managerial/organizational benefits (improves communication between managers, improves planning and control, improves utilization of management time), and personal benefits (deeper and wider exploration of alternatives, better decisions, possibility to cope with more complex decisions, increased decision confidence, clearer appreciation/understanding of problems). DeLone and McLean (1992) proposed a taxonomy and an interactive model as a framework in order to conceptualize and operationalize IS success. According to the model, the dependent variables of IS success consist of; system quality, information quality, system usage, user satisfaction, individual impact and organizational impact. A number of IS researchers have proposed refinements to the IS success models (for example Grover et al, 1996; Seddon, 1997; DeLone and McLean, 2003).

Mirani and Lederer (1998) offer an instrument for measuring the organizational benefits of IS. The instrument is classified in three dimensions: strategic (competitive advantage, alignment, customer relations), informational (access, quality, flexibility) and transactional (communication efficiency, system development efficiency, business efficiency). Torkzadeh and Doll (1999) develop an instrument for measuring the perceived impact of IS. The items were grouped into four constructs: task productivity (the extent to which an application improves the user's output), task innovation (the extent to which an application helps users create and try out new ideas), customer satisfaction (the extent to which an application helps the user create value for internal and external customers), and management control (the extent to which an application helps work performance). Wilson et al. (2001) summarize the benefits of using DSS, including the following: DSS supports group planning, resulting in focused debate, improved mutual understanding, and greater consensus; DSS can assist with identification of critical data requirements; and it increases planning confidence and enthusiasm.

Brown et al. (2001) present a large-scale linear programming optimization model used at Kellogg's to support production and distribution decision-making at operational and tactical levels. The usage of the model developed in-house at Kellogg's has resulted in better decision-making and overall cost savings. Gupta et al. (2002) describe a DSS that helps Pfizer plan its distribution network, with the model useful in strategic, tactical, and operational planning situations. The DSS has generated many benefits: improved transportation-scheduling support has led to savings in freight costs, elimination of customer deductions has amounted to several thousand dollars saved annually, and a strategic manufacturing plan has saved millions each year. However, the greatest benefits identified were the intangible ones: the DSS helped managers to understand the cost and service implications of proposed network alternatives. It also raised people's awareness of and ability to act on supply chain issues. It enhanced the firm's ability to remediate supply chain problems, resulted in proactive improvements, and increased people's confidence in the planning. Further, the DSS led to optimization modeling in other parts of the organization.

Fleischmann et al. (2006) explain the modeling of the DSS used at BMW to support strategic planning. The model made the planning process more transparent and was accepted by the many departments concerned, which provided the necessary data. The model reduced the planning effort and allowed planners to investigate various scenarios more frequently than they were doing in the past. All in all, it greatly improved the decision support for BMW's overall planning. Dehning et al (2007) examine the financial benefits of IT-based supply chain management systems. They suggest that SCM systems add value to the inbound logistics through the availability of more current and accurate information regarding orders that are shared with suppliers. In addition, SCM systems support operation processes by coordinating marketing forecasts, production schedules and inbound logistics. They also increase the firm´s ability to adapt to unplanned events. As a consequence, inventory levels and costs can be reduced and higher capacity utilization achieved.

Table 4: A summary of the IS benefits reported in the literature

References	Type of study	Benefits	Domain
Schroeder et al (1981)	Survey	Tangible measures of manufacturing performance and subjective benefits	MRP system
Money et al (1988)	Literature review	Operational benefits, managerial benefits, personal benefits	DSS system
DeLone and McLean (1992)	Literature review	System quality, information quality, system use, user satisfaction, individual impact and organizational impact	IS system
Mirani and Lederer (1998)	Survey	Strategic benefits information benefits, personal benefits	IS system
Torkzadeh and Doll (1999	Survey	Task productivity, task innovation, customer satisfaction and management control	IS system
Wilson et al. (2001)	Literature review	Focused debate, improved mutual understanding, assist with identification of critical data requirements, increase planning confidence and enthusiasm	DSS system
Brown et al. (2001)	Case study	Better decision support and overall cost savings	DSS system
Gupta et al. (2002)	Case study	Overall cost savings and intangible benefits	DSS system
Fleischmann et al. (2006)	Case study	Information benefits, improved decision support, reduced planning effort	DSS system
Dehning et al (2007)	Survey	Decision support, reduced inventory levels and costs and higher capacity utilization	SCM software

As can be seen in Table 4, surveys, case studies, and literature reviews have been used to identify the benefits derived from IS. Many different types of categorizations have also been suggested during the years. What is clear is that the focus has been rather wide. One has tried to create a generalized category of benefits that can be obtained in all SCM software, all DSS and even all IS.

2.3.2 Prerequisites to achieve benefits

The literature reports on a vast number of prerequisites to achieve IS benefits: Schroeder et al (1981) developed several regression models to relate MRP success to various independent variables. Four types of independent variables were suggested: the company characteristics (size, products and processes, complexity of product structure), type of MRP system (computerization, accuracy of data), implementation approach (management support, implementation method) and the starting level of manufacturing performance before the MRP implementation. Cox and Clark (1984) provide an extensive review of literature in manufacturing planning and control. They identified three problems with MRP implementations: management problems, technical problems, and people problems. The management problem consisted of poor pre- planning, a lack of co-operations, and procrastination. Technical problems were identified such as system design, data structure, file integrity, management of inventory levels and rescheduling. People problems included communication issues, system education, user participation, and system acceptance. Guimaraes et al (1992) produced a model consisting of the determinants for achieving DSS benefits. They were: the characteristics of the implementation process (top management support, user training, and user involvement), characteristics of the business task (task structure and certainty, task difficulty, task variability, and task independence), characteristics of the decision makers (organizational level and DSS experiences), and characteristics of the DSS (the supported phase level of managerial activity, and source of information), user-satisfaction with the DSS and user-perceptions of the DSS benefits.

The literature concerning ERP systems has mainly focused on identifying the critical success factors in the selection and implementation phase. Little has been done to identify the factors critical for success in the post-implementation phases (Häkkinen and Hilmola, 2008). On the top-ten list of the most commonly identified success factors in the ERP literature are: top management commitment and support, change management, business process reengineering and software configuration, training and job redesign, project team, implementation strategy and timeframe, consultant selection and relationship, visioning and planning, balanced team, and project champions (Finney and Corbett, 2007).

Recent evidence suggests that IT investments such as APS systems are most likely to provide benefits when well targeted, well timed, well managed and accompanied by complementary investments and actions (Dehning et al, 2007). It is important that the APS system selected suits the particular requirements of the company (Stadter and Kilger, 2005; Brun et al, 2006). Setia et al (2008) for example emphasize the task-technology fit and maintain that "*APS systems in a changing business environment is most appropriate for complex tasks with large number of products categories, frequent changing demand patterns, and uncertain supply conditions*". In their framework for organizational value creation from agile IT applications, such as APS systems, they propose three prerequisites for realizing value of an APS application. These are; (1) Organizational fit defined as the fit of the planning, scheduling and optimization capabilities of the APS systems with the supply chain objectives and strategy of the organisation (2) Process assimilation defined as the extent to which APS systems are used in the supply chain processes, and (3) Network adoption, the extent to which the APS processes is deployed across the supply chain network. In order to receive benefits out of the APS system, it is also important that the business process that is being supported is mature. Clause and Simchi-Levi (2005) stress that investment in advanced supply chain management software pay off only if solid business processes are in place. Conversely, implementing an IT system without those supporting processes can be a waste of money. Lin et al (2007) present a reappraisal of APS systems in industrial settings and propose an approach for APS systems implementation. They suggest that a business process reengineering should precede APS systems implementation and emphasize a human-centered design: humans should be empowered to take corrective control of system behaviour or planning results. Wiers (2002) describes the implementation of APS systems to support production planning and scheduling and concludes that it is important that the APS system is well integrated in the existing IT infrastructure in order to be used successfully. This is also supported by Stadler and Kilger (2005) who identify a strong coordination of APS modules and a strong integration of APS systems with ERP systems as a prerequisite to achieve consistent plans. Zoryk-Schalla et al (2004) examine the APS systems modelling process and highlight that modeling is a key success factor for implementation of APS systems. APICS (2007) highlights the importance of the collection and validation of data in all planning activities.

At a first glance it seems as if there are just as many prerequisites suggested as there are conducted studies. Looking carefully into the information presented above, it is possible, however, to discern that the prerequisites can possibly be derived from different phases in the IS implementation. There are, for example, prerequisites that are close connected with the selection phase. Other prerequisites are connected with the implementation and yet a few are connected with the post-implementation phase. Still, as suggested by for example Häkkinen and Hilmola (2008), relatively little has been done to understand exactly what the prerequisites are in the post-implementation phase.

2.4 Research questions

Based on the literature in 2.1-2.3, and the practical needs this section generates the research questions of the thesis. The research questions are rather broad, but more specified purposes is given in appended papers.

2.4.1 Research question 1

The manufacturing planning and control area have foremost been driven by practical people (Jonsson and Mattsson, 2009). This does not mean that academia has not developed theories; mathematical methods and algorithms for determining re-order points, order quantities, to solve planning and scheduling problems have all been developed during the years (Kreipl and Dickersbach, 2008). Only a few theories developed by academia have been put into practice (Lin et al, 2007; Wiers, 2009). The reasons for this are many; some stress that the computational capabilities of systems have been too low to handle operation research algorithms (Gayialis, 2004). Others stress that academia has not understood the importance of software packages in industries (McKay and Wiers, 2003). For example, it took about 15 years from the first installation of an MRP system until the theories of material requirement calculations were even mentioned to any significant extent in academic textbooks and journals (Jonsson and Mattsson, 2009). Yet, another explanation is that the methods and theories developed by academia are too complex to utilize in practice. One of the newest contributions launched from software vendors are APS systems and the expectations of what these systems are able to attain are high both from academia and industry in the subject area of manufacturing planning and control (e.g. Wiers, 2009). APS systems are said to support planners in creating feasible plans and is especially well-suited to environments where simpler planning methods cannot adequately address complex trade-offs between competing priorities. It is also said that mathematical methods and algorithms developed by academia finally can be put into practice since the advanced computer programming languages and the powerful hardware, support the usage of these algorithms (Gayialias, 2004). Still the knowledge of how APS systems are used in practice is relatively low (McKay and Wiers, 2003; Lin et al, 2007). There are, in other words, needs both from academia and industry to increase the knowledge of how APS systems can support manufacturing planning and control processes in practice.

RESEARCH QUESTION 1: How can APS systems support MPC processes?

The ambition of this question is to increase the understanding for how APS modules support the different planning tasks in MPC processes, i.e. in what way, and with help of what functionalities.

2.4.2 Research question 2

There has been an enormous amount of investments in IS since the end of the last century and today most companies make use of IS to support the MPC processes. Still, the evaluation of the IS investment has been a problem area for a long time because it is recognized that it is difficult to decide the value and the contribution of the investment (DeLone and McLean, 2003). Explanations for this may be that benefits mean different things to different people and that it is difficult to isolate the contribution of the IS functions from other contributors to performance (Chau et al, 2007). Besides, information system benefits can be captured at different units of analysis e.g. the system level, the individual level and the organizational level (Miriani and Lederer, 1988). When it comes to APS systems, few studies have been conducted to increase the understanding of what benefits the usage of APS system can result in (Lin et al, 2007). Even though some general ideas could be capture in studies of APS systems' precursors, it is important to understand the specific benefits obtained by APS systems. The knowledge of what benefits the usage of APS systems results in, is interesting also for practitioners. It is for example possible for senior executives to use it as one of several tools to assess whether the potential benefits of APS systems support overall business objectives. Thereby, they will be able to approve or reject different APS systems implementations. Alternatively, it is possible to employ it in the post-implementation phase as an evaluation mechanism to assess whether anticipated benefits were realized.

RESEARCH QUESTION 2: What potential benefits exists when using APS systems in MPC processes?

In accordance with Chau et al (2007) a benefit in this thesis is defined as the positive consequence of system use. Benefits in focus in this thesis relate to benefits closely connected to the system use and concerns benefits in the MPC processes.

2.4.3 Research question 3

Implementing APS systems is time consuming and expensive and it is in everybody's interest that the investment will pay off. In general APS systems are argued to support complex planning tasks. According to Setia et al (2008) *"firms with complex tasks characterized with a large number of product categories, frequent changing demand patterns and uncertain supply conditions can receive great benefits, while firms with less complex products or narrower product lines may find negative returns from APS systems due to the additional effort required to manage these tools"*. In other words, in some situations it might be better to make use of other planning tools than the ones available in APS systems. Keeping in mind that many APS systems implementations have failed or did not meet the initial expectations it is interesting to gain the knowledge for when APS systems is "the solution". Still it is not sufficient that the APS system fit the situation in order to obtain benefit in the end. For an IS investment to be successful it is important that it is well implemented in the organization and the IT structure and that IS are used in an appropriate manner by its users. A number of studies have examined and outline prerequisites for achieving system success of for example ERP and DSS systems. Still much of the IS literature has focused on identifying the critical success factors in the selection and implementation phases (Zhe and Kraemer, 2005; Häkkinen and Hilmola, 2008). There are in other words a need in the IS literature and the manufacturing planning and control literature of understanding which prerequisites to success that are underlying the post-implementation phase. Even though much can be learnt when scanning previous literature in the IS area in order to understand the prerequisite for system success of a particular system, the functionalities in systems differ and so do also the benefits achieved and the prerequisites that render benefits. There has been relatively little research on the requirements for successful use of APS systems and there is a need of increasing the understanding of how to successfully use APS systems.

RESEARCH QUESTION 3: What are the prerequisites for achieving benefits when using APS systems in MPC processes?

Prerequisite is defined as a factor that may affect the APS systems implementation (from the selection to the post-implementation phase) and the probability of conversion success. As in the case of benefits the focus is on prerequisites that are closely connected to the system use.

3. Methodology

This thesis consists of three independent studies, i.e. each study has its own research question, its own research design, and its own intended contribution. Despite the fact that each study is independent, they are all part of a greater whole: as input to the research questions and in the end to help fulfil the overall aim of the thesis. To understand the author's different standpoints and progress, as well as the problem-method-contribution fit of each study, this chapter has been designed as follows: It starts with a brief introduction of the research process, and then focuses on the research method selected, the selection of cases and the data collection techniques. In the last section, the quality issues of the research are discussed. Table 5 presents the link between the studies and the papers, the research method used in each study, the contribution of each study, the case company included in the studies, and the data collection techniques used in each study.

3.1 Research process

The research process started in February 2007 as a participant in the project "Integrating the Supply Chain through APS systems (ISCAPS)". The ISCAPS project is a joint venture research project between Chalmers University of Technology and Linköping University. It is funded by the Swedish government-owned authority Vinnova. The point of departure for the ISCAPS project was that the interest of APS systems was large but the knowledge regarding APS systems implementation and its usage was low. This was especially true on the strategic and tactical planning levels, which in turn motivated the focus on these planning levels. The overall purpose of the ISCAPS project was to investigate how the integration of the supply chain could be supported with APS systems.

When the author started her PhD studies there were, in other words, not a total confusion of what the thesis should deal with. It was therefore possible to formulate a "working purpose"; *"to increase the understanding of how APS systems are used in practice and to identify prerequisites for achieving a successful usage"*. The author was aware that the purpose probably would change during the process and kept it more as a help to stay focused. The author started to scan previous literature in different areas; operations management, operations research, supply chain management, logistics management, information systems, and production planning and control. Literature such as scientific journals, conference proceedings, business-oriented publications, and theses provided important background information. The aim with the literature review was to increase the author's personal knowledge about the subject area, to inform the author about the existing state of knowledge, as well as increase the author's understanding of the methodological handicraft. By understanding what had been done previously in the area and where the gaps were it also became possible to identify several problem areas and to formulate questions which needed answers. The literature review has been conducted during the whole research process. It has been a time consuming process since the author got sidetrack many times by other closely related areas (see Figure 4).

It was quickly discovered that a large source of confusion was the definition of APS systems. Not only was the term used to define different concepts, several terms were also used to define similar concepts. It was not possible to define APS systems only with help of literature; the author also needed some practical understanding. Together with another PhD student involved in the ISCAPS project the author interviewed APS systems consultants and system vendors stressing that they were using APS systems on the Swedish market. Interviews were also conducted with large ERP vendors who did not have a pronounced APS systems solution but offered software modules with similar functionalities. The following questions were asked: were APS systems meant for them and what functionalities were included in their systems.

Early into the research process, the author had the opportunity to join a study conducted by two senior researchers in the ISCAPS project. This study will from now on be referred to as Study I (Figure 4). The purpose of Study I was to explore how APS systems could be used for solving planning problems and identify perceived effects. The output from Study I was a research article, Paper I presented at Nofoma 2007. Study I resulted in a number of research directions. For example the feasibility of APS systems in situations with various planning complexity and how to achieve positive planning effects. The author became interested in these questions and Study II was designed based on these research directions. The purpose of Study II was to explore how to successfully use APS systems in the S&OP process. At first Study II resulted in one paper presented at Euroma 2008. After having been on parental leave for eight months, it was discovered that the first paper contained too much information. Therefore, the paper was split up into two parts: Paper II and Paper III (Figure 4).

Up to this point the focus had been on the strategic and tactical planning levels in accordance with the ISCAPS project. Still, most of the literature concerned the operational planning and it was also here that most of the applications were found. The author therefore wanted to increase the understanding of how APS systems were used in the detail planning to cover all planning processes and to be able to make some general conclusions about the APS systems usage in MPC processes. As a consequence Study III was designed. The purpose of Study III was to investigate how APS could support PAC activities and the perceived effects of doing so. The output from Study III was presented in Paper IV where a first version presented at Euroma 2009 (Figure 4).

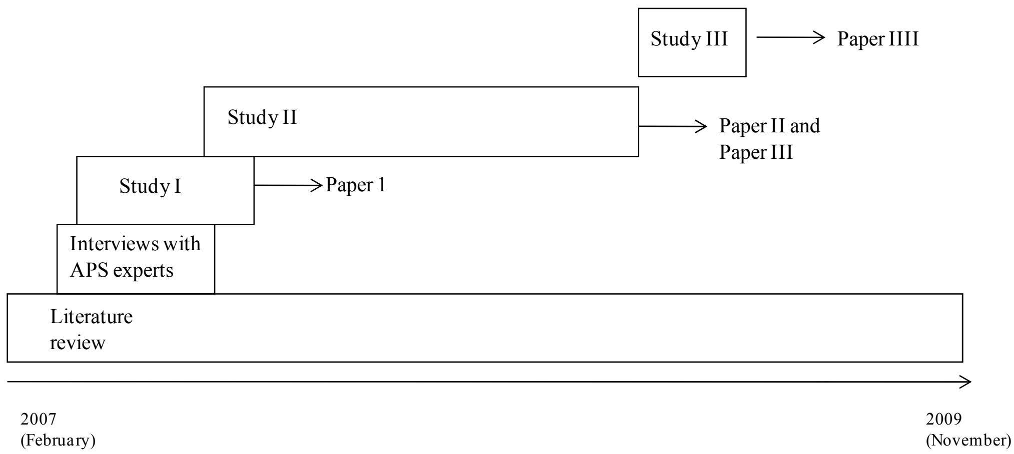

Figure 4: The research process

3.2 Research design

It is important to keep in mind that not all research questions can be answered by all research methods and one particular method cannot answer all types of research questions (Karlsson, 2009). Being aware of the confusion regarding different concepts in methodological discussions (Esaiasson et al, 2007), *method* is here defined as the technique of data collection and analysis (Karlsson, 2009). One method is not in itself better than the other but there should be a fit between the research question, the method and the intended contribution (ibid). In this chapter the research question, the method used and the contribution will be described for each study. Table 5 summarises the main conclusions.

3.2.1 Study I

The purpose of the first study was was to explore how APS systems could be used for solving planning problems at tactical and strategic levels, and identify perceived effects. This being so the aim was to describe how APS was used in companies and to explore which perceived effects that were achieved. Even though the research area was new for the author the senior researchers involved in the Study I had a general understanding and previous experiences which made it possible to formulate precise research question and produce an analytical framework before conduction empirical data. This facilitated the data collection and analysis of the empirical data. The intended contribution of the study was to increase the knowledge for how APS systems could be used and identify some areas which the use of APS systems could be related to. An important contribution of Study I was furthermore to generate future research areas.

The research method used in Study I was case study research. According to Voss et al (2002) case study research is a method which *"uses the data from case studies, either alone or triangulated with data from other sources as its bases"*. Yin (2003) stresses that case study research is particularly good for examining "how" and "why" questions, when the focus is on contemporary events and when the researcher does not have any control over behavioral events. Let us look at some alternative approaches. Action research points out the importance of cooperation with the actors in the system and focus on contemporary events (Coghlan et al, 2006). However, the researcher role is to take action, hence the researcher has control over behavioral events, which was not the case in Study I (or any of the other studies in this thesis). According to Yin (2003) surveys can be used when the researcher has no control over behavioral events and the focus is on contemporary events. As the use of APS systems at tactical and strategic levels are rare it would have been difficult (if not impossible) to identify sufficiency APS users to make a survey appropriate. Besides, there was a need to understand the planning process in which APS was used which would have been difficult if survey had been chosen.

3.2.2 Study II

The purpose of Study II was to explore how to successfully use APS systems in the S&OP process. First there was a need to understand what a successful use of APS system was, and after many discussions within the ISCAPS project and literature reviews a successful use was identified as the user's perceived benefits. With "use" the authors meant when to use APS systems (e.g. in which environment, in which planning tasks), and how to use APS systems in the activities. The contribution seen from the start was a "gross" list of prerequisites and perceived benefits and some linkages between them.

A case study research at one case company was selected as the research method. The reason for the choice was that the authors needed to understand the S&OP process in detail, for example which activities it consist of, which APS functionalities those are important in the different activities, which actors that does what, and how different APS modules are used to support the actors in their planning tasks. It would not have been possible to use action research as the author did not have any control over behavioral events. Neither was survey appropriate as survey is limited to the variables included and these variables must be known prior to the study (Merriam, 1998), which was not the case in Study II. In parallel with the case study a Delphi "type" of study was conducted. The reason was that the author wanted to extend the findings in the case study about which benefits that could be achieved when using APS systems and how to achieve them.

The objective of the Delphi method is to obtain the most reliable consensus of a group of experts. This method is a proven popular tool in IS research (Okdi and Pawlowski, 2004). In general, this method is primarily employed in cases where judgmental information is indispensable. Typically a series of questionnaires are used interspersed with controlled opinion feedback (ibid). In Study II a Delphi type of study was used with the aim of identifying prerequisites for a successful usage of APS systems in MPC processes, as well as identifying which benefits the usage of APS system foremost generates. The reason for why the Study II is called a "Delphi type" is that the study employed has many similarities with a Delphi study, but there are also some differences. A Delphi study does not depend on a statistical sample; instead it requires qualified experts who have a deep understanding of the issue (ibid). Fifteen industry, academia, and consulting representatives with experiences from APS systems implementation and usage, were selected and included in the study group. This group corresponds well with the recommendations of 10-18 experts given by literature (ibid). In a Delphi study the respondents are anonymous. That was not the case in this study.

The independent experts were invited to a workshop. Before the workshop they were asked to identify additional prerequisites and to add benefits to a list that was produced with help of literature and previous experiences through the case studies conducted during the project. They were also asked to rank to what extent they perceived that the suggested prerequisites result in successful usage of APS systems and to what extent they perceived that the listed benefits would occur. They were asked to rank their answers on a seven point scale (ranging from very poorly to very well). The mean of the ranking and a revised list were thereafter presented to the experts in a workshop. During the workshop the list was discussed and adjusted and a new list based on the results from the workshop was developed. The experts were thereafter asked to rank the new list. The results from the second round were discussed with the expert group, who considered them to represent relevant consensus ranking of potential benefits.
If Study I was characterized as being focused this was not the case in Study II which can be seen as a learning process where many things fall into place. The analysis in this case was more difficult than in Study I as the analytical framework changed in parallel with literature screening and data collection.

3.2.3 Study III

In Study III, the research question was from the beginning formulated in order to explore how APS systems are used in PAC and the user's perception of using APS systems in PAC. The contribution seen from the beginning was to produce a framework for how APS could support the different activities in PAC and identify pros and cons of doing so. An analytical framework was produced before conducting the data which made the data collection and analysis easier. The research method chosen was case study research as the author needed to understand the PAC process in detail and how APS could support this process.

During the data collection and the analysis, a number of factors, so called shop floor characteristics, were identified. This influenced how APS systems were used in PAC activities. This sparked the interest to further investigate these findings and a new research question was formulated. The purpose was to investigate how the manufacturing process, shop type, and data quality influence the use of APS system. The contribution was to understand in which way these shop floor characteristics influenced the PAC activities when APS systems were used. From the theory and the experiences from the first case study, a structured framework was produced defining the shop floor characteristics and the different ways APS systems could be used in PAC activities. Again the method of case study research was used as the way to conduct and analyze data. According to Voss (2002) it is not uncommon for the research question to evolve over time as, for example, the research may shift from theory building to theory testing. This should be seen as an asset to the research since it allows the development of more knowledge, as opposed to a fixed research question. Still, it is important to not use it as an excuse for inadequate specifications of research questions.

3.3 Selecting cases

There are several choices to take into consideration when conducting a case study research; how many cases that should be used, case selection and sampling. It is usually said that the fewer cases, the greater opportunity for depth of observation (Yin, 2003). On the other hand it is difficult to generalize conclusions, models and theories developed from a single case (Voss et al, 2002). By using multiple cases the depth of study might decrease as resources are constrained. On the other hand, it can also augment external bias and help to guard against observer bias (ibid). It is important that cases are not only selected on basis of finding the most accessible site, the selection also needs to incorporate the specific reason why one needs a particular group of cases (Yin, 2003). Due to the rich information that case studies provide, traditional sampling logic is seldom used to select cases (Voss et al, 2002). It is instead recommended to select cases based on diversity and the potential to contribute to the research objectives (Arbnor and Bjerke, 1997). The usage of APS systems at strategic and tactical planning levels is rare, therefore, the author did not have unlimited choices. The author took help of the researchers in the ISCAPS in the first two studies and by APS vendors and consultants in Study III as the author asked for a list of companies that had implemented APS systems in PAC activities. Based on this list the author called the companies and talked with representatives to make a first screening if the company matched the selection criteria.

In Study I the number and selection of cases were already decided upon when the author entered the study. Reflecting on the number of cases, it ought to be an appropriate number of cases as the research question was to describe how APS systems can be used and explore what perceived effects it could generate. The three case studies were selected since they all used APS-modules for solving planning problems on a strategic/tactical level. In Study II the author needed to understand the S&OP process in detail and get into many different viewpoints. A single case study was suitable for this task and the selection criteria this time was a company using APS systems to support the S&OP process, and which also had the requirements to achieve benefits from the usage. In the first phase of Study III the author wanted to develop a detailed understanding of how APS systems may be used and what pros and cons it meant for the actors involved in the PAC activities when APS systems were supported. A single case study was chosen to fulfil the research aim and intended contribution. In the second phase of Study III, three shop floor characteristics were identified as influencing the usage of the APS systems, the manufacturing process, the shop type and the data quality. After a first screening three case companies using the same APS module and with different shop floor characteristics was identified and used.

3.4 Case companies

Seven case companies were included in this thesis. They are here briefly presented in the order of the conducted studies. Table 5 shows which case companies are included in which studies.

Case company A: is one of Scandinavia's leading producers of vegetable oils and fats. In 2005, it merged with a Danish company. Case company A uses an APS system for a supply chain design evaluation on how to utilize two identical production sites in the most optimal way. Case company A was included in Study I.

Case company B: is one of the leading groups within the drover and agriculture industry in Sweden. It is a producer cooperative that works together on marketing, distribution, sales, processing and supply. Case company B uses an APS system to support the master production scheduling process and was included in Study.

Case company C: is the biggest Nordic manufacturer of heavy steel plates. An APS system is used as a support to the master production scheduling process. Case company C was included in Study I.

Case company D: is a company in the chemical industry that manufactures, markets, sells and distributes chemicals used at the surface of other chemicals. The case firm is divided into three regional organizations: America, Asia, and Europe, the latter of which is studied in this thesis. Case company D uses an APS system to support the S&OP process and was included in Study II.

Case company E: is a division of the business area construction and mining technique at a Swedish manufacturing company. It develops and produces drilling machines. Case company E uses an APS system to support PAC and was included in Study III

Case company F: manufactures garage doors. Case company F consist of three production sites whereof the production site in Sweden is studied in this thesis. Case company F uses an APS system to support PAC and was included in Study III.

Case company G: develops, manufactures, and globally markets metal cutting solutions. The company consists of several production sites and the focus in this thesis is on the production site in Sweden. Case company G uses an APS system to support PAC and was included in Study III.

3.5 Data collection

Typically, the prime source of data collection in case study research is structured interviews, often backed up by unstructured interviews and interactions. That is also the structure of this thesis. Other sources of data used are attendance at meetings and events, surveys, and collection of internal reports. In this section the data collection methods used in the thesis are described. Table 5 presents the data collection techniques used in the different studies.

3.5.1 Interviews

Personal interviews are used when there is a need to address complicated questions where the opportunity to a follow-up with new questions is of value to the study. Multiple respondents were used in all studies when it was impossible to identify one single person who had all of the required knowledge, or when the events being studied had different ways of interpretation. In Study II and III, for example, many perspectives were needed to answer the research questions. In some of the interviews in Study I and II, there were often more than one interviewer but only one interviewee. According to Eisenhardt (1989) the use of multiple interviewers can enhance the creative potential of teams and the convergence of observations increases the confidence in the different findings. Semi-structured interviews have been used in all studies carried out in this thesis. Kylén (1994) stresses that semi-structured interviews usually are flexible and that they minimize misunderstanding. Usually the interviewees have been given the questions before hand. The interviewees were thereby able to prepare themselves and check up the information that they were uncertain about. This, in turn, made the interview process smoother. Besides personal interviews, site visits, participation at meetings, educational lessons have been used. They have not been as structured as the personal interviews. The reason for this is that the situation has contained communication with many actors involved, in an uncontrolled environment.

3.5.2. Documentations

Data collected through written sources, such as internal data, presentations, books, articles and the Internet are useful when it is important to quickly obtain insight and understanding of the environment in question. Power point presentations including information about the planning processes and the APS systems project have been used in all studies. Other sources used are, internal data such as description of priority rules, rules for master data etc. The Internet has been used in all studies. The documents have in general been mentioned during the interviews and thereby raised the author's interest.

3.5.3 Questionnaire

A questionnaire facilitates data collection in large populations and contributes to a low cost per object. It is important that the questions are simple and the responses well- defined for the respondent. Questionnaires were used as a method of finding information in Study II. A questionnaire was emailed to all actors involved in the S&OP process. Each respondent was asked to rate how well 18 listed benefits corresponded to their perception of using APS systems in their day-to-day work and in meetings on a seven point scale (ranging from very badly to very well). The aim of the questionnaire was to find out if there were any differences in perceived benefits among different actors and different activities in the S&OP process. The questionnaire was based on a literature review, previous interviews at the case company, and input from a Delphi type of study. It was sent to three co-workers at the author´s department, in order to receive feedback, before it was sent to the respondents. In order to make sure that the respondents understood the concepts, the author spoke to the key informant at the case company and adjusted part of the vocabulary to better fit the case company´s terminology. It was not possible to conduct a significant statistical analysis as the number of respondent was too small. Instead the result from the questionnaire was used to identify tendencies among the different actors' perceptions.

3.6 Research quality

What is good research is partly approach dependent (Karlsson, 2009). To establish the quality of case study research four tests are commonly used as a basis for validity and reliability; (1) Construct validity, which occurs in the data collection and composition, (2) Internal validity, which occurs in the data analysis, (3) External validity, which occurs in the research design, and (4) Reliability, which occurs in the data collection (Yin, 2003). The studies in this thesis have been conducted with these case study tactics. Table 5 presents which tests that are used in the different studies.

3.6.1 Validity

Construct validity means that the operational measures used to measure the constructs actually measures the concepts they are intended to measure (Karlsson, 2009). According to Yin (2003), this first test is especially problematic when conducting a case study. Critics of case studies point to the fact that a case study investigator fails to develop a sufficient operational set of measures and that "subjective" judgments are used to collect data. As mentioned earlier the concept APS systems caused some confusion, and a lot of time was given to set the definition of APS system. The author tried many different ideas, for example defining APS by its functionalities, and defining APS systems by comparing APS systems with ERP systems. However, the author decided to use the same definition as APICS and defined each module under investigation rather than defined APS systems as a whole. The definition used by APICS is also the most widely used. The MPC processes and the framework of APS systems in S&OP and PAC activities, were derived from the MPC literature which made these concepts operational. The definitions of benefits and prerequisites were a bit more difficult to set as there are many different opinions of what benefits and prerequisites mean. After reading several articles on IS research, the author eventually found definitions which were well established operational concepts and corresponded well to the meaning of the word in this study. To further construct validation, experts in the Delphi study were asked to validate the author's interpretation and categorization of the variables (Okoli and Pawlowski, 2004). According to Voss et al (2002), one way to increase the construct validity is by using multiple sources of evidence; something that has been used in this thesis shown by the usage of several data collection techniques. Besides, key informants have always reviewed the written case draft, which is another tactic to enhance the construct validity (Yin, 2003). The author has also taken into consideration the "chain of evidence", i.e. it should be possible for an external observation to trace the evidentiary process backwards.

Internal validity means that the study actually measures what it is meant to measure and that demonstrated relationships are explained by the factors described and not by any irrelevant factors (Karlsson, 2009). In Study II and ,III relationships were being investigated to some extent as for how benefits are created in Study II and how different factors influence the usage in Study III. According to Yin (2003) the specific tactics for achieving internal validity in case study research is difficult to identify. Still he recommends pattern-matting, explanation-building, and logical models as tactics to enhance internal validity. In Study II a model was produced with the help of literature and previous experiences, this model was made before data was collected at the case study. A number of theoretical propositions were also formulated in Study II and III before data was collected. The author decided that when analyzing the data she would use these propositions and main components in the model. The empirically based patterns were then compared with the theoretically based patterns. Subsequently, the former was based on what was actually happening at the case company implementing APS systems whereas the first was based on what would happen at the case company (based on the predicted outcomes).

External validity means that the results are valid in similar settings outside the study objects (Karlsson, 2009). According to Yin (2003) the external validity problem has been a major barrier of doing case studies and a frequently heard question is *"how can you generalize from a single case?"* The answer to this question is: case studies are possible to generalize in theoretical propositions but not in populations (ibid). This being so, the goal is not to enumerate frequencies (statistical generalization) but to expand and generalize theories (analytical generalization). In analytical generalization, the investigator is striving to generalize a particular set of results to some broader theory (ibid). In all three studies effort has been made in creating a theoretical framework, which has been the main vehicle for generalizing the results.

3.6.2 Reliability

Reliability is the extent to which a study's operation can be repeated with the same results (Voss et al, 2002). The goal of reliability is to minimize errors and bias in a study. According to Yin (2003) this is done by documenting as many steps as possible and to conduct the research as *"if someone were looking over your shoulder"*. In all studies conducted in this thesis, a case study protocol has been used to deal with the documentation problem in detail. The protocol is more than a questionnaire as it contains not only the questions to be asked but also the procedures and the general rules to be followed (Yin, 2003). The research protocol used in this thesis has outlined the subjects to be covered during the interview, stated the questions to be asked and indicated the specific data required. The protocol has served both as a prompt for the interview and as a checklist to make sure that all topics have been covered. The research protocol was piloted in initial the interviews with some key informant at the case companies. To improve reliability, notes have also been taken during all interviews, site-visits, meetings, and workshops (Voss et al, 2002). After each interview, site-visit, workshop or meeting, the author has expanded the typed notes. For example, the author has commented on problems and ideas that arose during the interaction with the case company. Pretesting of questionnaires (was made in Study II to enhance reliability (Okoli and Pawlowski, 2004).

Table 5: An overview of the studies

An Overview of the studies	**Study I**	**Study II**	**Study III**
Link between paper and study	Paper I	Paper II and Paper III	Paper IV
Research question	Explore how APS systems can be used for solving problems at tactical and strategic levels, and to identify the perceived effects of using APS systems	Explore how to successfully use APS systems in the S&OP process	Explore how APS could support PAC and the perceived effects of using APS systems in PAC Investigate how the manufacturing process, shop type, and data quality influence the use of APS systems in PAC?
Contribution	Identify patters and come up with hypothesis and further research areas	Identify variables and to some extent explain relationships	Increase the understanding for the relationships between variables
Research method	Case study	Case study, Delphi "type of" study	Case study
Case company	A,B,C	D	E,F,G
Data collection method	Interview, documentation	Interview, documentation, questionnaire,	Interview, documentation

4. Summary of appended papers

This chapter contains a brief summary of the papers included in this thesis with the focus on the results, and the contributions. Note that the full papers are appended to the thesis. Table 8 describes the author's different roles in the attended papers.

4.1 Paper I – Applying advanced planning systems [2] for supply chain planning: three case studies

Paper I introduces the use of APS systems in tactical and strategic planning processes and connects it theoretically and empirically to four areas; planning complexity, planning model and design, planning data and planning organisation.

4.1.2 Summary of the paper

The purpose of this paper is to explore how APS systems can be used for solving planning problems at tactical and strategic levels, and to identify the perceived effects of using APS systems. The study is based on literature review in the area of supply chain management, manufacturing planning and control and APS systems, and empirical data from three manufacturing companies using APS systems for solving planning problems at tactical and strategic level. The data collection is based on interviews, site visits, and internal documentation.

4.1.3 Results and contribution

The paper shows that even though all case companies used APS modules for solving planning problems on strategic and tactical levels, it was used a bit differently among the different companies. One case company used APS modules to generate decision support for cost efficient supply chain design, whereas the other two companies used APS modules for continuous master production scheduling in situations with finite capacity constraints. Still, in all cases the overall aim was to create holistic perspectives of complex planning problems, eliminate sub-optimization and achieve commitment to an "optimum" plan.

In accordance with the literature (de Kok and Graves, 2003; Chopra and Meindl, 2004) APS modules were used to deal with high planning problem complexity. Nevertheless, the type of complexity differed between the case companies. All case companies dealt with complexity in turn of a large number of variables. Some also dealt with multiple business constraints and decision rules. In line with previous studies (e.g. APICS, 2007) it was found that the usage of finite planning put a higher requirement on up-dated work center data. Although many assumptions and simplifications of the problems were made in all case companies, the perception was that the output was good enough. The gathering and registering of basic data was not considered to be problematic in any of the case companies. For all case companies, several organizational units were involved and affected by the planning process. For two of the three case

[2] In this first article advanced planning systems (APS) was used instead of advanced planning and scheduling (APS) systems.

companies it was more important to generate commitment to one single plan than finding the optimal plan.

The planning effects identified were for example; slightly higher transportation costs due to lower fill-rates, decreased production costs and less capital tied up in inventories because of better throughput, reduction of the total planning time, increased control of the material flows and cost structure, decreased process and demand uncertainties, and increased communication between logistics, manufacturing, marketing, and sales functions. It was found that the planning organisation had an important role in the perceive effects.

The paper contributes with increased knowledge in an unexplored area as it investigates how APS can be used for solving planning problems at tactical and strategic planning levels and identifies the perceived effects of doing so. The paper also generates some research issues; the feasibility of APS in situations with various planning complexities, how design of the optimization model creates complexity and affects the planning process, data gathering requirements, the role and design of the planning organisation and how to achieve positive planning effects.

4.2 Paper II – The potential benefits of advanced planning and scheduling system in the sales and operations process

Paper II focuses on the positive effects of APS usage i.e. the benefits in the S&OP process and is influenced by the following research area, "how to achieve positive planning effects", identified in Paper I.

4.2.1 Summary of the paper

The purpose of this paper is to explore the potential benefits achieved by using the APS system in the S&OP process. In particular, the paper tries to structure different types of potential benefits, and find out if the benefits perceived are different in the S&OP activities. The purpose is also to find how the usage of APS influences the perceived benefits. The research methods used are a case study and a Delphi study. The case company is a company in the chemical industry with long and wide experiences of using APS modules in the S&OP process. The group of experts in the Delphi study consisted of fifteen industry and consulting representatives with experiences from APS implementation. The data collection is based on interviews, questionnaires, and documentations. An analytical framework is built up with the help of previous literature and experiences describing the S&OP activities, the aim of each activity, the potential APS support and the potential benefits. The potential benefits when using APS in the S&OP processes is categorised into three main groups; decision support, planning efficiency, and learning effects.

4.2.2 Results and contributions

A list of eighteen potential benefits was identified with the help of the interviews at the case company and the Delphi study with APS experts (see Table 6). It was found that the APS users in the case company perceived many benefits connected to decision support, planning efficiency, and learning effects. This corresponds well with previous literature where improved decision support and better decision making (Brown et al, 2001; Gupta, 2002; Fleischmann et al, 2006), reduced planning effort and identification of necessary data (Fleischmann et al, 2006; Jonsson et al, 2007). Decision support benefits were according to APS experts and APS users the type of benefits most likely to be achieved.

The case study analysis showed that the benefits perceived in the S&OP activities were a bit different and that it depended on the aim of the activity, how the system was used, i.e. which functionality that was exploited and on user characteristics. In the activities concerning the preparation and generation of delivery plans, the perceived benefits mainly concerned learning effects. In the activities concerning the generation of a production plan, the benefits were foremost found in the planning efficiency. In the S&OP meeting, decision support benefits were valued the highest. This corresponds well with the conclusions made by Amoako-Gyampah (2004) who found that different groups of organizational members have different perceptions of the benefits associated with an innovation. How the system is utilized was influenced by the system design and by access to data-planning. This also corresponded with previous literature (e.g. Zoryk-Scalla, 2004; APICS, 2007).

The paper contributed with the knowledge of which benefits can be expected when using APS systems. This is interesting considering the great amount of effort put into developing advanced planning and scheduling algorithms in the area of manufacturing-planning and control, and the minor act of actually understanding what the usage of these algorithms results in (Lin et al, 2007). Besides, the paper contributes to IS literature as there is a need for better understanding the value creation in the post-implementation phase (Zhu and Kraemer, 2005; Häkkinen and Hilmola, 2008). The findings have several managerial implications. They can assist companies in understanding the benefits to be expected from its usage in the S&OP process. The case study analysis gives further insight into how APS systems may be employed and what benefits different APS systems user-categories may expect when it is used in an appropriate way.

Table 6: The potential benefits when APS system is used in the S&OP process

Decision support benefits	**Planning efficiency**	**Learning effects**
Allows visualization of information	Results in high data quality (e.g. capacity, lead times, safety stocks, customer data)	Results in good knowledge about the planning processes
Makes information (e.g. customer, markets, capacity) easy to access	Gives focus on data quality	Results in good knowledge about the supply chain
Makes it possible to identify unexpected future events	Simplifies planning activities	Makes the planning activities important
Makes it possible to analyze unexpected future events	Lead to less time spend on planning activities	Makes the planning activities enjoyable
Make it possible to analyze the problem picture and solve the problem as a whole		
Allows quantifiable what-if scenario analysis		
Results in reliable delivery plan (low forecast error)		
Gives optimal/feasible plans		
Gives integrated plans		

4.3 Paper III - How to utilize advanced planning and scheduling systems in sales and operations planning

Paper III focuses on the prerequisites when using APS systems in the S&OP process. In particular it aims to answer the question of when to use APS systems. Also this paper was inspired by one of the research issues generated in Paper I; the feasibility of APS in situations with various planning complexity.

4.3.1 Summary of the paper

The purpose of this paper is to increase the understanding of how to utilize APS functionalities in S&OP processes. The study was carried out at the same company described in Paper II. A theoretical framework is developed with the help of literature on manufacturing planning and control, explaining which functionalities to use in different S&OP processes according to the S&OP planning task complexity, and the overall S&OP aim (Figure 5). The theoretical framework suggests that the need of APS functionalities (integral planning, optimization, concurrent priority and capacity planning, and simulation) in the S&OP process depends on the overall aim of the process and also on the planning task complexity. There are two fundamental types of aims; 1) to create a platform for cooperation and coordination, in order to create consensus among one set of goals and plans. 2) to generate optimum plans, such as an optimal overall supply chain profit as the target function. Planning task complexity was defined as consisting of five complexity attributes (number of entities, variety of entities, dependencies among entities, uncertainties, and constraints), arising within the organization or in the downstream or upstream supply chain. The APS needs were suggested to be lower when a clear optimization aim was absent and when the planning task complexity was lower.

4.3.2 Results and contribution

The case study analysis shows how several positive effects were reached from using APS functionalities in an S&OP process belonging to quadrant III in Figure 5: high planning task complexity and no optimization aim of the S&OP process. Integral planning was a highly demanded and valued functionality at the case company. Since the most important aim of the S&OP process was to create cooperation, coordination and also to create consensus among goals and plans (Ling and Goddard, 1988; Bower, 2006), the results were not very surprising. Still, optimization, concurrent priority and capacity planning and more extensive what-if simulations, ought to be some important enabler for more mature S&OP processes. It was also found in the case study analysis that a given degree of complexity was needed in order to make the APS investment financially appealing. It indicates that the complexity depends on the tradeoff between the effort of making it work and the potential benefits to be gained from the investment. The case study also indicates that “high complexity” is a matter of the level of complexity of each individual attribute as well as the number of attributes. It was found that management problems, technical problems and people problems present obstacles for how successfully the APS functionality may be used. Examples of such obstacles were the access and the quality of planning data, as well as system acceptance. This corresponds well with previous studies (e.g. Torkzadah and Dwyer, 1993; Zhau and Lee, 1993; Petroni et al, 2002; APICS, 2007; Jonsson and Mattsson, 2008).

The paper contributed to theory in manufacturing planning and control by developing a framework of when to employ APS systems in S&OP processes and by improving the understanding of the relationships between the planning task complexity, the S&OP aim and the APS usage. Several issues for further research were also generated, which is an important output of the study, since the study area is quite unexplored. This paper also contains important managerial implications. Therefore, the framework developed and presented in this paper can be used for companies assessing the APS functionalities needed in the S&OP process. The case study analysis gave further insight into how APS functionalities can be used to support the different S&OP activities and which problems and benefits APS usage can result in.

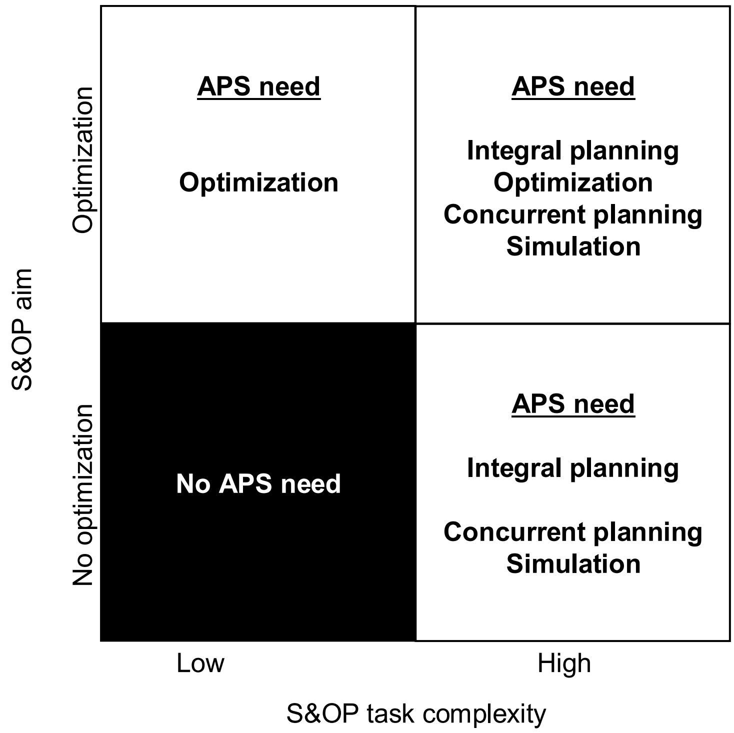

Figure 5: S&OP task complexity, S&OP aim and APS systems need. Quadrant I represents a situation with low S&OP task complexity and no optimization aim. Quadrant II represents a low S&OP task complexity and optimization aim. Quadrant III represents a high task complexity and no optimization aim, and quadrant IV represents a high task complexity and optimization aim.

4.4 Paper IV- Shop floor characteristics influencing the use of Advanced Planning and Scheduling systems

Paper IV focuses on the use of APS in the PAC activities. This being, Paper IV is the only one of the four papers dealing with the usage of APS system on the operational planning level.

4.4.1 Summary of the paper

The purpose of this paper was to investigate how the manufacturing process, the shop type and the data quality i.e. shop floor characteristics influenced the use of APS systems in production activity control (PAC). The methodology used was multiple case studies at three case companies with different shop floor characteristics, who all used the same APS module for supporting production scheduling. A theoretical framework was generated relating the three shop floor characteristics to the four PAC activities (order release, sequencing, dispatching, and reporting). Several aspects to take into consideration when using APS in the PAC activities, were derived from literature in manufacturing planning and control (Table 7).

4.4.2 Results and contribution

APS systems were used to support PAC activities in the three case companies. One in particular, the production scheduling module, supported the scheduling and dispatching activities. It was also found that the production planning module could be used to support the order release activity. The case analysis showed that the shop floor characteristics influenced the APS supported PAC activities, whereas the shop type and data quality influenced the decision of how often to make the APS run and which freedom to give to the shop floor. The manufacturing process influenced how the dispatch list was created. The data quality was in turn influenced by the reporting from the shop floor and the feedback given to the shop floor.

It was found that the manufacturing process was not a crucial factor for deciding if or if not an APS system ought to be implemented. Instead, it is important to identify the scheduling problem and investigate if the problem is suitable to handle with an APS system. In literature in manufacturing planning and control, it is many times argued that advanced scheduling algorithms, such as those employed in APS systems, are most suitable in job shop processes (e.g. Vollmann et al, 2005; Jonsson and Mattsson, 2009). This study showed that APS systems were also successfully used in line-processes characterized by sequent dependent setup times. It is usually presumed that a high quality of data is a must if making more advanced scheduling tools successful (Lin et al, 1995). This study found that the level of data quality needed depended on how the APS system was used; if the APS system was used as a guide, the need for high data quality was not as great. If, however, it was used to give detailed schedules with precise operation timing and sequences, high data quality was needed. In accordance with Wiers (2009) the case analysis showed that the shop type had a large influence on the APS usage at the shop floor.

The paper contributes with knowledge on how different shop floor characteristics influence the APS supported PAC activities, and which aspects to consider when using APS at the shop floor. The study covers previous literature by analyzing how APS systems influence PAC as a whole. The study has managerial implications since the main aspects identified in the study may be useful when implementing APS in PAC.

Table 7: Summarizes the main aspects to consider when APS systems are used in the PAC activities.

Activities in the PAC process	**Aspects to consider**
Order release (orders downloaded from the ERP system or the APS production module to the APS production scheduling module)	(1) How far in the future are orders released to the shop floor? (2) How is consideration taken to capacity, tools and materials before, under and after the APS run?
Sequencing (the dispatch list is created in APS module)	(1) How often is APS ran? (2) How is the dispatch list created?
Dispatching (the dispatch list is implemented)	(1) Which information does the dispatch list include? (2)What decision freedom is given to the shop floor?
Reporting	(1) In which way do the personnel report? (2)How is feedback given to the shop floor?

Table 8: Authors' responsibility for the appended papers

Paper	**First author**	**Second author**	**Responsibilities**
I	Patrik Jonsson and Martin Rudberg	Linea Kjellsdotter Ivert	The first authors stood for the largest part of the data collection, the paper planning, analysis and writing. The second author participated in data collection at one case company and participated in the paper planning and some of the writing
II	Linea Kjellsdotter Ivert	Patrik Jonsson	The paper's planning and analysis were equally shared among the authors while the data collection and writing have been the first author´s responsibility
III	Linea Kjellsdotter Ivert	Patrik Jonsson	The paper´s planning, analysis and writing were equally shared among the authors. The first author took the largest part in the data collection
IV	Linea Kjellsdotter Ivert		Sole author

5. Discussion

In this chapter the four research questions and their answers are discussed. The four appended papers contribute to the overall research questions in different ways, which are described in Table 9. The theoretical and practical contributions of the thesis are also discussed in the end of this section.

Table 9: The contribution of each paper to the research questions

	Paper I	Paper II	Paper III	Paper IV
RQ1	Describes how APS systems can solve planning problems in the MPS process and in supply chain design decisions	Describes how APS systems are used in the S&OP process and how APS functionalities support S&OP activities		Describes how APS systems supports PAC activities
RQ2	Identifies perceived effects of using APS systems in MPS processes	Identifies eighteen potential benefits when APS systems are used in the S&OP process	Identifies perceived effects of using an APS system in the S&OP process	Identifies perceived effects when APS systems are used in PAC
RQ3	Relates planning complexity, planning model and design, planning data, and planning organisation to the use of APS systems	Identifies several of factors that affect the users perceived benefits	Relates the planning complexity task and the aim of the S&OP process to the need of APS functionalities	Investigate how the manufacturing process, the shop type, and the data quality influences the use of APS systems

5.1 The practical use of APS systems

The first research question was formulated as: *how can APS systems support MPC processes?* All four papers contribute with information to this question as can be seen in Table 9.

The multi-site production planning module was used for continuous MPS and S&OP with finite capacity constraints as well as for generate decision support for cost efficient supply chain design. While it is not very surprising that the same module may be used in the S&OP and MPS processes as there are large general similarities between these processes, it may be more surprising that the multi-site master planning modules were used to support a strategic decision concerning the configuration of the supply chain. Many APS systems vendors do not offer a strategic network planning module; instead the multi-site master planning module is used to cope with the strategic decision as well as generating delivery, distribution, and production planning plans.

In the MPS and S&OP processes the multi-site master planning module and the demand planning module were used to support a central planning organization when streamlining the planning process in question. Earlier, this had been carried out locally. Even though there were many similarities between how these modules were used at the case companies, there were also some differences. Master data such as bill of materials, stock, capacities, operation times, and transportation times were extracted from the company's ERP system. Linear and mixed-linear programming were used to balance supply and demand for each time bucket during the planning horizon according to some predefined target functions. Still the target functions in the cases were different. In case company B the solver engine was used to minimize costs since large profit margins was not the goal as much as cost reduction. In case company C and D, maximization of profit was important and therefore the optimization was done on profit maximization. The demand planning module was used in combination with the multi-site production planning module in case companies B and D. Case company C did not use a demand planning module. The demand planning module supported sales managers by producing a sales forecast based on statistical forecasting methods and experiences. In case company B a module in the ERP system supported the sales function with the same task. In case company D the information in the demand planning module was visualised at a planning meeting with the aim of generating a delivery plan. In case company C the information of the demand plan module was transferred directly to the multi-site production module.

Paper III showed that the functionalities integral planning, optimization, concurrent priority and capacity planning, and simulation were important functionalities derived from the master production module in the activities in order to prepare, adjust and settle the production plan. Integral planning made it possible to include all production sites. Optimization supported decisions such as which and how large volumes to produce at each site according to a predefined target function. Concurrent priority and capacity planning made it possible to consider available capacity. Finally, simulation made it possible to look at what happens if demand is changing. Furthermore, integral planning was an important functionality derived from the demand planning module in the activities to create the sales forecast and the delivery plan. This was the case because it made it possible to integrate different departments/ business units in the demand planning process.

The production scheduling module was used to support PAC activities. Paper IV identifies some main aspects to consider when utilized in this process (Table 7). It was found that the production scheduling module was mainly used to support the activities sequencing and dispatching, whereas order release and reporting were only indirectly influenced by the usage of the production scheduling module. As in the case of the MPS and S&OP process the case companies used APS differently. Case company E implemented the module to reduce tied-up capital, lead times, and to improve delivery times. The APS run was conducted every morning and a dispatch list was generated with the help of priority rules and consideration was taken to available capacity. Consideration was not taken to maintenance and the prototype shop, in the capacity calculations. Case company F implemented the module to optimize and sequence one operation with sequent dependent setup times that limited the performance of the entire production system. Case company F did not have any capacity problems, therefore the functionality finite capacity scheduling was not used. The APS system was run four times a week and configuration keys were used to set the sequence in the bottleneck operation. Case company G implemented the production scheduling module in order to reduce lead times and increase the utilization rate in the machines. As in case company F, one major problem was sequent dependent setup times at one operation. The APS run was conducted three times a day and generated a dispatch list for four production sites with dispersed locations since many products needed to be processed at several production sites. The APS modules were used to sequence the bottleneck operation and the sequence was based on a number of keys. Consideration was also shown to available capacity where maintenance was included in the capacity calculations but the prototype manufacturing was not included.

5.2 The benefits of using APS system

The second research question was formulated as follows: *what potential benefits exist when using MPC processes?* Also, in this case all four papers each contributed with some information when answering the question. Still, except from Paper II, all papers identified perceived effects of using APS systems. In other words, both positive and negative outcomes were identified in the other papers.

Paper I identified a number of perceived effects of implementing APS systems. Still it is more or less impossible to identify which benefits were derived from the APS implementation and which were derived from other factors. APS systems were implemented in connection with large structural changes and reorganizations, This made it difficult to recognize which effects came from the APS systems implementation and which came from other factors. It was suggested that it would be appropriate to identify the perceived effects *in* the process and not *by* the process. In general, MPC processes are said to improve customer service, lower inventories, decrease customer lead times, stabilize production rates, and reduce production and storage costs (e.g. Vollmann et al, 2005). APS systems are supposed to support MPC processes in fulfilling these aims, but *how* are the APS systems supporting the MPC process?

This question was answered with the help of Papers III and IV where participants involved in the MPC process were asked to identify the perceived effects of using APS systems in the process. A number of effects were identified in these two papers that could be connected to the usage of APS systems in the process. For example, the central planning organisation in case D stressed that the APS system has resulted in a comprehensive view that was not present before. The business and sales managers believe that they spend too much time with the system, considering the small output they receive from it. Production managers, and contract manufacturing representatives stress that the usage of APS modules help them stay one step ahead. The production scheduler and the foreman in case company E identified that the APS model could not handle realistic complexity and that many assumptions needed to be made. Besides, APS models suffered from "final state problem" meaning that small changes in the status of the shop floor cause major changes in the production schedule. In case company F it was identified that "even if the APS module is not used to its full extent it is a very important tool for the shop floor performance, which we could not do without".

Still the research question has not been answered to its full extent. In Paper II a list of eighteen potential benefits were identified in the S&OP process by the help of APS users and APS experts. These benefits were categorized into three main groups of benefits. Benefits with a clear connection to the APS functionalities, so called decision support benefits; benefits connected to the increased data quality and simplified planning activities, so called planning efficiency; and benefits connected to the increased understanding of the process and the confidence in the planning of tasks, so called learning effects. Table 6 shows the benefits identified in each category. Even though the benefits within each group are S&OP specific, the categorization could most likely be used for the other MPC processes as well.

5.3 The prerequisites to achieve APS system benefits

The third research question was formulated such as: *what are the prerequisites for achieving benefits when using APS systems in MPC processes?* As shown in Table 9, this question was also answered with the help of all papers. When identifying prerequisites that may affect the APS implementation, one discovers that there are an overwhelming amount of prerequisites present. These prerequisites do not only concern the direct usage of the system, for example which functionalities that are used by the user to solve a specific problem. The prerequisites also relate to how the system was implemented and selected. The four papers have focused on different phases in the APS implementation (e.g. the selection phase, the implementation phase, and the post-implementation phase). In each phase, some prerequisites have been identified.

5.3.1 The selection phase

Paper III investigated when it is appropriate to use APS systems in the S&OP process. A framework was developed, linking the need of four APS functionalities (integral planning optimization, concurrent capacity and priority planning, and simulation) to the overall aim of the S&OP process (consensus and/or optimization) and the S&OP planning task complexity (number of entities, variety of entities, dependencies, uncertainties, and constraints)(Figure 5). It was assumed that the need for APS functionalities should be lower when a clear optimization aim was absent and when the planning task complexity was lower. In the case study analysis, it was found that several positive effects were reached by using the APS functionalities in an S&OP process characterized by planning task complexity and an aim to reach consensus.

Despite the fact that the framework is designed for the S&OP process, the fit between the planning task complexity and the APS functionalities and the fit between the aim of the process and the APS functionalities, should be important dimensions also in the other MPC processes. APS systems are usually said to support complex planning and scheduling tasks (e.g. Setia et al, 2008; Rudberg and Thulin, 2009). This conclusion is supported by Papers I-IV. The case companies were characterized by a large number of entities (e.g. production sites, products, suppliers, customers) as well as different varieties between the entities. In several companies there were also dependencies shown among the entities, business constrains and uncertainties. Still, it seems as if there is a limit for how much complexity an APS system can handle in practice. In Paper IV it was for example found that it is much more challenging to implement an APS system in a shop floor characterized by much uncertainty as APS systems suffer from the final state problem. Paper I found that the complexity of the optimization conducted in the planning model increased with the complexity of planning tasks. The overall aim of the process influenced the APS functionalities needed. For case company A, in Paper I, the cost-optimized output was considered the most important output for the planning. On the other hand, for case companies B and C, the importance was to generate commitment to one single plan throughout the organization, rather than finding the optimal plan. Subsequently, the functionality optimization was highly valued in case company A, whereas functionalities such as concurrent planning and priority control were more important in case company C. This was the case because one important aim of the APS systems supported MPS process was to handle excess demand.

It can be argued that the advantages of an optimal planning process decreases when there is a shorter length of the planning horizon; in the PAC process, for example, it is more or less impossible to achieve an optimal plan. In planning processes with shorter planning horizon, high precision and detailed information, a third dimension in the framework should probably be added, namely, the need for rescheduling. Many times, particularly planning processes concerned with detail planning, have a great need of rescheduling which places a need for APS functionalities. APS systems are also said to support frequent rescheduling (e.g. Genin et al, 2007). Still, as emphasised earlier, it was identified that APS systems are not superior when supporting frequent rescheduling.

In summary: The aim of the process and the planning task complexity, are identified as prerequisites in the selection phase which should influence the need of an APS system implementation. Still, it is important to emphasise that an APS system has the possibility of generating a positive outcome even in situations with low planning task complexity and the lack of aim for optimization. The need of APS systems is lower in that situation and it would probably be more suitable to use a simpler planning method. Still, there seem to be an upper level of how much complexity the APS system is capable to handle.

5.3.2 The implementation phase

The design of the model and access and quality of planning data influenced the use of APS systems. In Paper III for example, participants in the S&OP process were disappointed that the APS system was not able to support decisions such as from which contract manufacturer to buy capacity. The reason for why it was not possible to support these decisions was due to the model setup, which in turn was due to lack of access to planning data. The scheduler in case company E in Paper IV identified that the assumptions in the model resulted in irritations at the shop floor as the plan did not correspond to reality. This in turn meant that the plan had to be circumvented, causing the performance criteria the plan was based upon, to suffer. Papers III and IV reported on the importance of data quality. The central planning organization in case company D stressed that it would have been possible to use APS systems to a larger extent if it were not for the low quality of system-data. However, it was discovered that the required level of data quality depended on how the APS systems were used. One main conclusion of Paper I was, for example, that finite planning puts higher requirements on up-dated work-center data, compared to infinite planning. In Paper IV it was found that if the output from APS systems was used as a guideline, the required level of data quality was not very high. However, if autonomy was given to the APS system, a high quality of planning data was required.

The capabilities of the APS systems also seemed to influence the APS usage and the perceived effects. The APS system in case company E, for example, suffered from the final state problem, meaning that small changes in the status of the shop floor cause major changes in the APS system-produced dispatch lists. This was also one of the reasons why APS systems could not be used to reschedule every single disturbance on the shop floor, which in turn resulted in that many actors perceived the dispatch list did not corresponded with the reality. In this thesis, only commercial off-the-shelf APS systems have been analyzed. One drawback of commercial off-the-shelf information systems, is usually that it is impossible to model the actual complexity and solve the resulting optimization model in a realistic way because the model is not customized to the specific situation.

Summary: three prerequisites which may affect the probability of the conversion success, were identified when APS systems were used which could be related to the implementation phase: the design of the model, access to and quality of planning data, and the capabilities of the APS system.

5.3.3 The post-implementation phase

In Paper II it was found that the aim of the S&OP activity, the usage of an APS system to support the tasks, and the user characteristics influenced the perceived effects. It was for example found that the aim of the activity corresponded well with the benefits one perceived. This may seem obvious, since these are the benefits one would expect if the APS system is used appropriately in the activities. It was also possible to link the perceived benefits to the functionalities used in the APS modules. In the activity with the aim of creating a preliminary production plan, optimization, concurrent planning and simulation were used and the participants perceived that the usage of APS systems had resulted in an optimal plan and allowed for what-if simulations. The user characteristics seemed to matter as actors responsible for the S&OP process and spending much time working with the APS system were found to perceive more benefits than those spending less time working in the APS system and those who only participated in some activities in the S&OP process.

The design of the planning organization was also identified as important to the result since it created prerequisites in the form of time, training and support of the users to work with APS systems. In cases B and C, in Paper I, and in case D in Paper III, the central planning organizations acted as centralized planning functions. They worked actively with the involved parts, by planning meetings, and with education and training. In Paper III it was found that to fully use the potential of the APS systems, one should have a mature S&OP process and aim for a profit optimization. In case company D, the APS system supported S&OP

process had been active for six years; still the case company had not reached the highest maturity level. One reason might have been that the central planning organization had been responsible for the whole process development as well as the APS system implementation. The central planning organization focused on coordinating material flows between the many sites and to reach consensus, but had not aimed for optimization. Therefore, the full APS system potential could not be realized. System acceptance and support from consultants were other prerequisites identified in Paper III as important to a successful usage of APS systems. In Paper IV it was found that an APS system requires high discipline of its users, especially if autonomy is given to the system. It is, for example, important that the data figures in the system are correct and up to date and that the dispatch list is followed to the largest possible extent.

Conclusion: six prerequisites were identified in the post- implementation phase. These may affect the probability of conversion success (perceived benefits): how APS systems were used (which functionalities that were used, and which planning tasks it supported), user characteristics, planning organization, system support, system acceptance, and high user-discipline.

5.4 Contributions

This thesis contributes with increased knowledge of the usage of APS systems in MPC processes. It has described how an APS system can be used in practice; explored which benefits can be obtained; as well as identified prerequisites for successfully using APS systems in the MPC processes. In particular the thesis has explained how an APS system can support the different S&OP activities and which functionalities that are of importance in each activity. Furthermore, it has identified the main aspects to consider when APS system is used in the PAC process. It has explored several perceived effects when using APS systems in MPC processes and identified eighteen potential benefits which exist when using APS in the S&OP process. It has also identified several prerequisites which may affect the APS system implementation and the probability of conversion success. A framework has been created explaining when it is appropriate to use APS systems in regards to the overall aim of the process and the complexity of the planning-tasks. It has been shown that there is a limit of how much complexity an APS system can handle in practice. As the complexity of the model increases with the complexity of the planning tasks, the assumptions made to make it work may lead to unrealistic plans. Besides, it was identified that APS systems suffer from final state problems, which make them inappropriate for usage in an environment characterized by many uncertainties.

The contribution should be of interest to the subject area manufacturing planning and control. Researchers may benefit from the determined definition of APS systems as well as the definition of planning-task complexity presented in this thesis. Also, identified variables (benefits and prerequisites) when investigating the success of different approaches and methods for manufacturing planning and control. For managerial usage the identified benefits may be utilized as a tool to assess whether the potential benefits of APS systems support the overall business objectives. Thereby they will be able to approve or reject APS system implementations. Alternatively, it can be employed in the post-implementation phase as an evaluation mechanism to access whether anticipated benefits were realized. The framework suggesting when APS systems should be appropriate can support managers in the decision of whether to make an APS system investment. The findings on how to utilize APS systems should be an important tool for guiding companies in how to get the most out of their investment. Finally, the contributions from this thesis should be of interest for consultants as they give good insight into how APS systems are actually used in practice and user experiences.

5.4 Contributions

This thesis contributes with increased knowledge for the use of APS system in MPC processes. It has described how an APS system is used in practice, explored which benefits that can be obtain, as well as identified prerequisites for successfully using APS systems in the MPC processes. In particular the thesis has explained how APS system can support the different S&OP activities and which functionalities are of importance in each activity. Furthermore, it has identified the main aspects to consider when APS system is used in the PAC process. It has explored several perceived effects when using APS systems in MPC processes and identified eighteen potential benefits that exist when using APS in the S&OP process. It has also identified several of prerequisites that may affect the APS system implementation and the probability of conversion success in the selection phase, the implementation phase, and the post-implementation phase. A framework has been created explaining when it is appropriated to use APS systems with regard to the overall aim of the process and the complexity in the planning tasks. It has shown that there is a limit of how much complexity an APS system can handle in practice. This as the complexity in the model increases with complexity in the planning tasks and the assumptions made to make it work might lead to unrealistic plans. Besides, it was identified that APS systems suffer from final state problems, which make them inappropriate to use in an environment characterized by much uncertainties.

The contribution should be of interest for the subject area manufacturing planning and control. Researchers can benefit from the determined definition of APS systems and the definition of planning task complicity sat in this thesis and identified variables (benefits and prerequisites) when investigating the success of different approaches and methods for manufacturing planning and control. For managerial use the identified benefits can be used as one several of tools to assess whether the potential benefits of APS systems support overall business objectives. Thereby they will be able to approve or reject APS system implementations. Alternatively, it could be employed in the post-implementation phase as an evaluation mechanism to access whether anticipated benefits where realized. The framework suggesting when APS systems should be appropriate could support managers in the decision of if or if not to make an APS system investment. The findings about how to utilize APS systems should be an important knowledge for guiding companies in how to get the most out of their investment. Finally, the contributions from this thesis should be of interest for consultants as they give good insight in how APS systems are actually used in practice and which pros and cons the users perceive.

6. Conclusions and further research

The expectations of APS systems have been high, both from academia and industry in manufacturing planning and control. It is for example said that operation research algorithms finally can be put into practice and that APS is the most relevant innovation in the world since the introduction of MRP systems. Relative to the massive interest there has not been much written about how APS is used in practice and what effects an APS approach truly results in. These are interesting opinions considering the vast number of algorithms developed by academia and the fact that many APS implementations have failed or did not meet the initial expectations. This section concludes the thesis and gives directive to future research.

6.1 Conclusion

The overall aim was to study the use of APS systems in manufacturing planning and control (MPC) processes. Three research questions were formulated, which in turn were answered with help of three case studies.

The first research question was formulated as follows; how are APS systems used in the MPC processes. To answer this question, case studies were conducted at seven companies where APS systems were used to support different MPC processes. It was found that the multi-site master planning module was used in the S&OP and MPS process and supported the central planning organization produce feasible production, distribution, and delivery plans. A framework was developed, describing how APS systems are able to support the S&OP activities. Four APS functionalities, in particular, were of great importance; integral planning, optimization, concurrent priority and capacity planning, and simulation. Still, the functionalities were used a bit differently in companies which depended on other things than the aim of the process and the planning problem in question. The multi-site master planning module was also used to support strategic decisions concerning the configuration of the supply chain. The demand planning module was used in the S&OP and MPS processes to support sales managers in producing a sales forecast and a preliminary delivery plan. The production scheduling module was used to support the PAC activities. In particular, activities such as sequencing and dispatching were supported by the production scheduling module and the aspects to consider were how often to make the APS run, how to create the dispatch list, which information to include in the dispatch list, and which decision freedom to give the shop floor.

The second research question was formulated as; what potential benefits may be achieved when using APS systems in the MPC processes. To answer this question a Delphi study and several case studies were conducted. It was found that the usage of APS systems resulted in three types of benefits; (1) Benefits with a clear connection to APS functionalities, so called decision support, (2) Benefits connected with simplified planning activities, so called planning efficiency, and (3) Benefits connected with increased understanding and gained knowledge, so called learning effects.

The third research question were formulated as: which are the prerequisites for achieving benefits when using APS systems in MPC processes. It was identified that prerequisites which may affect the probability of conversion success occur at all phases during an APS implementation. Therefore, prerequisites were separated into three groups: those identified in the selection phase, those identified in the implementation phase, and those identified in the post-implementation phase. The prerequisites in the selection phase were; the aim of the MPC process, the complexity in the planning tasks. A framework was developed suggestion in which S&OP processes (in which type of S&OP aim, and which type of planning task complexity) it is appropriate to use certain APS functionalities (integral planning, optimization, concurrent priority and capacity planning, and simulations). The prerequisites in the implementation phase were; the design of the model, access to and quality of planning data, and the capabilities of the APS system. The benefits in the post-implementation phase were; the usage (functionalities used and tasks it supported), user characteristics, planning organization, system support, system acceptance, high discipline of users.

The thesis has contributed increased knowledge for the usage of APS systems in the MPC processes, which should be of interest for the subject area manufacturing planning and control. In particular, the definitions in the thesis, the identified variables, and the frameworks should be of interest to researchers, management personnel, and consultants.

6.2 Future research

This thesis opens opportunities for further research. Either one stays on the track and continues increasing the understanding for the usage of APS systems as a whole by answering the question of how to use APS system in order to create benefits. There are many models within the literature of IS that can be modified to APS systems. That way one does not need to invent the wheel over again. Such an example is the IS success model of DeLone and McLean (1992) and the Ives et al.'s IS research model (1980) which can be combined into one model explaining both the dependent (IS success model) and the independent (IS research model) variables. Another suggestion is to identify the minor parts and do some more thorough research on one or a few of the identified variables. It could for example be interesting to increase the understanding of the relationship between the decision support benefits and the APS capabilities. As well as to understand the relationship between system acceptance, APS usage, and perceived benefits. Yet another interesting area to further explore is the question of when to use APS system. It may be interesting to develop the framework further and investigate companies in other areas of the framework and companies in other MPC processes. This thesis focuses on benefits; however, there is also a financial side of APS. To fully understand the APS performance, it is necessary to balance the costs and benefits of its usage. This is an interesting phenomenon to study in future research.

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Paper I

Applying advanced planning systems for supply chain planning: three case studies

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Abstract

Purpose – The purpose of this paper is to explore how standardized advanced planning systems (APS) can be used for solving planning problems at tactical and strategic levels, and to identify the perceived effects of using APS.

Design/methodology/approach – Multiple case studies involving three cases using APS software for strategic network planning and master production scheduling are conducted. Comparative analysis explores how the planning situation, the model design and use of the APS impact the perceived planning effects.

Findings – Findings show how APS support cost-optimized strategic network design in one case and how efficiency, capacity utilization and delivery service problems were decreased in two cases using APS in global master planning processes. The cases show how APS supports cross-functional integration and supply chain commitment to a common plan. Research directions are suggested about the feasibility of APS in situations with various planning complexities, how design of the optimization model creates complexity and affects the planning process, data gathering requirements when using APS, the role and design of the planning organization, and how to achieve positive planning effects, such as finding global optimum and single plan commitment.

Research limitations/implications – The approach is descriptive and explorative. Only three cases are studied.

Practical implications – The findings present experiences of APS usage and identify issues to consider when using APS and potential benefits to gain from usage.

Originality/value – The practical use of APS is low and the knowledge about how it impacts supply chain planning and performance is unexplored. The findings of this paper fill some of these gaps.

Keywords Supply chain management, Process planning, Systems software

Paper type Case study

1. Introduction

The vision of the supply chain as a holistic construct with close cooperation between the different organizational units has replaced the traditional picture of it as a collection of vertically organized functional units (Stadtler and Kilger, 2005). This, however, leads to a complex planning situation with multiple items, produced at multiple work centres in multi-site production systems. The supply chain complexity is not only a function of the number of links, nodes and items in the network. It is also

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affected by the level of inter-relationship between the organizational units and variations in organizational culture, size, technology, etc. (Choi and Krause, 2006). Strategic decisions are made over a long planning period, when there is no detailed knowledge of many decision parameters, making the decision environment very uncertain. In the same time, the strategic planning is important as it sets the frame for the tactical and operational decisions and many times involves high investments and is costly to change (Zoryk-Schalla *et al.*, 2004). Typical strategic decisions concern the production and distribution capacity, the location of facilities and which products to be manufactured at each plant (Colotla *et al.*, 2003). Melo *et al.* (2005) put forward some problems connected to these kinds of decisions; for example, problems of deciding in which periods the capacity of a given set of facilities should be extended to meet increasing demand, problems of deciding were to locate facilities, and problems of optimizing the joint logistics when companies are merging. Planning problems of this kind are often quite complex to solve, especially if aiming at optimum solutions, taking capacity constraints and profitability into consideration.

While being aware of the broad area covered by supply chain management (SCM), the research in this paper focuses on advanced planning systems (APS), the recent software development that supports planning of the supply chain. Unlike traditional enterprise resource planning systems (ERP), APS try to find feasible, near optimal plans across the supply chain as a whole, while potential bottlenecks are considered explicitly (Stadtler and Kilger, 2005). In terms of software, APS means a broad group of software applications developed by various software vendors, e.g. i2, Manugistics, Oracle, SAP, AspenTech and Lawson. During the last decade, the use of APS for design, integration, and control of supply chain processes have increased. Especially, the interest among industrial companies has increased, some have invested in the software, but only few use them in practice on strategic and tactical planning levels. Almost no research has been conducted about APS usage. There are very few documented cases showing how standardized APS are used, especially descriptions of successes or failures of using APS for supply chain planning (SCP) on strategic and tactical levels. No broader based empirical study testing and explaining the effects of using APS as support for SCP has been identified. The understanding of when and how to utilize the potential of APS for managing supply chains and what effects could be expected are consequently scarce, both in practice and academia. This gap needs to be closed in order to understand when and how to use APS in SCP.

The purpose of this paper is to explore how standardized APS can be used for solving planning problems at tactical and strategic levels, and to identify the perceived effects of using APS. This is done through a comparative analyze among three Swedish firms using APS for solving strategic and tactical supply chain problems. In the following sections, we describe the methodology and the frame of references. Section 4 examines the case studies. They are analyzed in Section 5. Finally, the paper is concluded in Section 6.

2. Methodology

The research is based on a literature review and three case studies. The literature review is founded in the fields of SCM, manufacturing planning and control and APS. Three cases using standardized APS for solving different types of planning problems at tactical and strategic levels were selected in order to compare and contrast APS usage in the cases. The case studies are descriptive and explorative in nature, and data have been gathered through semi-structured interviews and on-site visits at the case companies, as well as from company internal data and presentations. The authors also had access to primary data in terms of company reports describing processes, performance data, etc. Typically, interviews were carried out with project managers, master planners, and members of the implementation team. To reduce the risk of misinterpretation, at least two researchers participated in the interviews (Kylén, 1994), and case descriptions were communicated back to the interviewees. Interviews were also followed up by telephone and e-mail to verify and clarify data if needed. Furthermore, one author has previous project experiences from two case companies. Another author has done studies with the main respondent of the third case company, increasing the understanding of the companies, its problem and planning processes.

The cases are analyzed based on five areas that are proposed to be important when analyzing the appropriateness of applying APS in company specific planning environments. The five areas are; planning complexity, planning model and design, planning data, planning organization and planning effects, which are further described in the last section of the frame of references.

3. Frame of references

During the last few years not only APS niche vendors, but also ERP vendors have started developing and implementing advanced planning modules, with the aim to support complex planning problems. APS as a standard decision support system (DSS) for production and distribution planning is, however, still a new and fairly unexplored tool (Stadtler and Kilger, 2005; Wu *et al.*, 2000).

3.1 Supply chain planning using APS

To be able to plan and control complex supply chain structures powerful management decision support is needed. Planning has, therefore, in the recent years found a renaissance in the use of optimization and simulation tools. APS uses such optimization and simulation tools. It considers the supply chain constraints and produces near optimal plans and is therefore sometimes called supply chain optimization software. Cost minimization and profit maximization are the two most common ways to control the solution (Stadtler and Kilger, 2005). APS can be defined and explained through different perspectives but commonly APS is viewed as an extension of ERP. On the other hand, standard APS modules stem from the many in-house developed DSS that aid planners at various levels in the decision hierarchy (de Kok and Graves, 2003). The literature reports on some successful implementations of DSS in either special SCP situations or optimization models regarding the entire chain. Gupta *et al.* (2002), for example, describe a DSS that helps Pfizer to plan their distribution network. The model is useful in both strategic and operational planning situations. Brown *et al.* (2001) presents a large-scale linear programming optimization model used at Kellogg Company to support production and distribution decision making on both operational and tactical levels. Arntzen *et al.* (1995) comprehensively describe supply chain optimization at Digital Equipment Corporation.

Nowadays, APS-modules are often a part of larger software suites and work as add-ons to existing ERP-systems. APS does not replace ERP, it extracts data from the ERP database and sends the resulting plans back for distribution and execution. Often, solver engines based on linear and mixed integer programming is used to unravel the large amount of data. To cut computing time, heuristics are used built on operations research knowledge (de Kok and Graves, 2003). APS, consequently, tries to automate and computerize the planning through simulation and optimization. Still the decision-making is done by planners who have insight in the particular supply chain, know about the system constraints and also have a feeling about feasibility in the plans that are created. Planners also do the modelling and decisions regarding use of input to the model. APS is, thus, based on a systems and process approach and tries to bridge the gap between the supply chain complexity and the day-to-day operative decisions. Three main characters of APS are; integral planning, true optimization and hierarchical planning system (Fleishmann and Meyr, 2003). Stadtler and Kilger (2005) define the goal with APS as "…to find feasible, near-optimal plans across the supply chain as whole, while potential bottlenecks are considered explicitly."

3.2 Structure and functionality of APS

Considering the complex environment that most companies have to cope with, most DSSs advocates a hierarchical distribution of the decision-making processes, where the next upper level coordinates each lower level (Wortmann *et al.*, 1997). Strategic decisions (long horizon and long periods) cannot be based on the same level of detail in the information as is the case for operational decisions (short horizon and short periods). Hence, decisions made at a high hierarchical level are normally based on aggregated information (in terms of product families, factories, etc.) and aggregated time periods. Thereafter these high-level decisions form the context for the decision-making processes at lower-level decision centres, where decisions are disaggregated into more detailed information and time periods, but the considered horizon is made shorter. Decisions are thus exploded through the hierarchical structure until the lowest level is reached and detailed decisions are executed (Figure 1).

One way to classify standard APS is by categorizing different modules depending on the length of the planning horizon on the one hand, and the supply chain process that the module supports on the other. Figure 1 shows the most common standard APS modules according to these two dimensions (Stadtler, 2005; Meyr *et al.*, 2005).

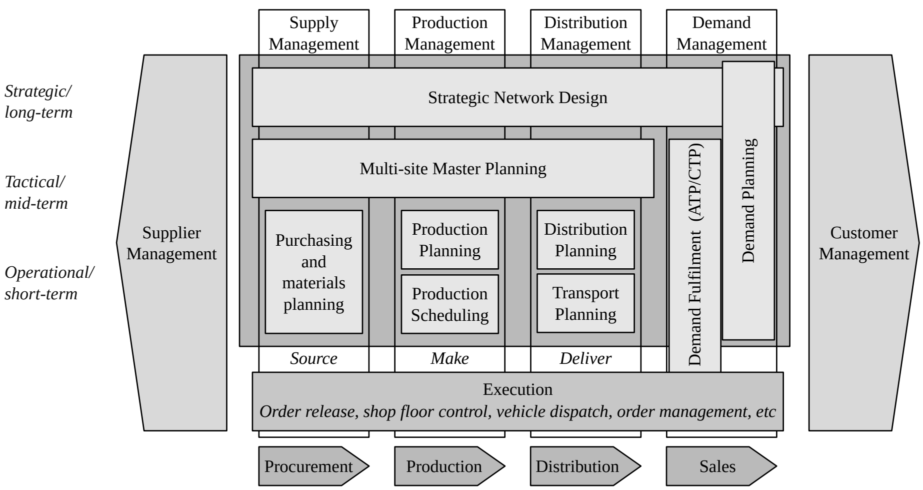

Figure 1.
Typical APS planning structure and categorization of APS modules

This module segmentation is commonly used among software vendors. This study focuses on the strategic and tactical levels, i.e. strategic network design (SND) and multi-site master planning (MMP) in Figure 1.

SND is intended to provide support for key strategic decisions concerning the configuration of the supply chain on a three to ten years planning horizon (Entrup, 2005). The SND module must tie together all relevant decision variables and constraints over a long planning horizon leading to that product, capacity and customer data must be aggregated to get a solvable model size. Owing to model complexity and solvability, stochastic features are typically not included in standard APS, although future estimates incorporate a high degree of uncertainty (Entrup, 2005). Instead, companies typically develop a set of scenarios to establish upper and lower bounds and a typical (most realistic) case. The models are defined as LP or MILP models depending on the planning issues to address and to achieve reasonable solution times a great deal of technical expertise is required to limit the model size (Goetschlalckx *et al.*, 2002). Hence, the primary users are business development departments or consultancies. Companies using a SND model normally run it either as a one-time analysis as a part of a supply chain redesign project, or on an annual basis during the yearly budgeting process. Although the results of the SND module have the highest impact on the supply chain (Entrup, 2005) there are still only few companies using it on a regular basis.

MMP aims at synchronizing the flow of materials along the supply chain, and thereby balancing demand and capacity. It supports the mid-term decisions concerning efficient utilization of production, distribution and supply capacities (Stadtler and Kilger, 2005). MMP not only balances demand with available capacities but also assigns demands (production and distribution amounts) to sites in order to avoid bottlenecks, wherefore it has to cover one full seasonal cycle, or at least 12 months in terms of weekly or monthly time buckets. Owing to the complexity and detail required in the model only constrained (or near-constrained) resources are modelled in detail. To increase the solvability of the model, most vendors distinguish between hard and soft constraints in the LP or MILP model that is used (Entrup, 2005). While hard constraints have to be fulfilled, the violation of soft constraints only renders a penalty in the objective function. As for the SND module, also the MMP model uses aggregation to establish reasonable solution times. The solvers included in the standard APS modules are often a combination between internally developed and third party solvers. Companies using the MMP module often have an established sales and operations planning process or a centralized master planning function. One important feature of the MMP module is the ability for companies to coordinate sourcing, production, distribution and seasonal stock decisions on a multi-site basis. Besides the positive planning effects the MMP is also intended to enhance visibility and coordination throughout the supply chain. Yet, the MMP module is seldom found at companies today, although it has gained more interest in recent years.

3.3 Using APS

Studies show that there are several problems involved in efficiently and effectively using planning software. Several of these problems are related to the planning complexity, software complexity, lack of training and knowledge among managers and personnel, low-data accuracy, and lack of support from the software vendor (Petroni, 2002). Most of these studies focus on ERP systems, especially MRP environments. Studies on ERP implementation also conclude that top management's support together with personnel education and training about the software and planning processes are of vital importance for successfully implementing an ERP system, but also for running the system after implementation (Petroni, 2002; Muscatello *et al.*, 2003). The findings should be possible to relate to APS applications as well (Stadtler and Kilger, 2005). The problems could be expected to be even more severe for APS, for example, because several functions and organizations may be involved in the planning process and because the requirement of real time data may be higher than in ERP. We propose that the appropriateness of using APS could be related to the following areas:

- *Planning complexity.* Dealing with high planning problem complexity is a main feature of APS (de Kok and Graves, 2003; Chopra and Meindl, 2004). We could distinguish between complexity in the physical supply chain structure (e.g. the number of links, nodes, capacity processes, item groups) and complexity in decision making (e.g. including several trade-offs between different business constraints and decision rules such as customer and item priorities). It is reasonable to believe that the appropriateness of using APS increases when the planning complexity increases. But there may also be situations that are too complex or containing "wrong type" of complexity for APS to solve.
- *Planning model and design.* The APS effects should also be affected by the planning model design, i.e. how the appropriate optimization functions, aggregation levels and number of constraints for a specific planning problem is chosen. Various types and degrees of complexity may also affect the appropriateness of using cost and profit optimization. It is also reasonable to believe that standardized APS may have some drawbacks compared to custom-made APS, because the optimization problem differs between companies and it is hard to create an APS that fits many companies well.
- *Planning data.* All planning is based on a vast amount of data. This is also the case for SCP using APS. The need for accurate data is especially high when working with finite capacity and real-time planning (APICS, 2007). Data collection and validation, consequently, have to be conducted in appropriate ways. The amount and accuracy of data and ease of designing and analyzing SCP models on strategic and tactical levels also depend on the level of data aggregation. Higher aggregation levels results in fewer planning objects and could reduce the uncertainty in the planning data, but on the expense of lower details. The same effects can be achieved by using larger time buckets. Furthermore, strong coordination between the different planning modules is a must in order to achieve consistent plans for the different planning levels and different entities in the supply chain (Stadtler and Kilger, 2005). Besides, APS need to be integrated in an existing IT infrastructure, for example, APS needs to be integrated with ERP and data warehouses storing the basic data. Planning data problems concern in what planning situations the gathering and registering, and resulting quality, of basic planning data is critical for the APS planning performance. There are obvious links between planning complexity and the criticality of data gathering and registration.
- *Planning organization.* Solving complex SCP problems using APS is not only an issue of designing a proper optimization model and securing accurate basic data.

> The design and functioning of the planning organization may also have important impact on the planning performance, especially when different functional and organization units affect and are affected by the planning. It is not obvious what characterizes appropriate planning organization design in different planning situations, for example, when conducting event-based planning, involving geographically distant sites, requiring global visibility of critical paths and what if analysis. Neither, is it clear what education and training is necessary in order to utilize the potential of APS for planning on strategic and tactical levels.

APS, consequently, deals with complex planning problems, using an optimization-based planning model and design, relying on a vast amount of planning data and is carried out by a planning organization. The case study analysis focuses on these issues and the perceived effects of using APS.

4. Case studies

The three cases use standard APS-modules for solving planning problems on a strategic or tactical level. All companies are continuous process type companies and use "supply chain planners" from different vendors, although they face different planning problems.

4.1 Case I – AArhusKarlshamn

4.1.1 Company characteristics and planning problem. The company AArhusKarlshamn (AAK) is a recently established company making vegetable oils and fats. It emerged through a merge between the Danish company Aarhus United A/S and the Swedish company Karlshamns AB. Marketwise, the two companies complement each other well; Karlshamns with large markets in Scandinavia and Central and Eastern Europe and Aarhus United with strong market positions in Western Europe, the USA and Latin America. The presence in North America offers great opportunities for expanding the companies within speciality fats. Both companies also have ambitions within the fast food market, which can be based on a very strong foundation in the UK. In terms of purchasing, the merger may also lead to efficiency gains. Both companies source many of their raw materials in South East Asia and Africa. Cooperation and a strong foothold in the markets could possibly strengthen the company's competitive ability.

Another outcome of the merger is that it has left the new company with two identical production sites in the same geographical area, Northern Europe. It is not obvious how to utilize the two facilities in the most optimal way, i.e. what assortment to make at the respective site or what markets to serve from the respective site.

4.1.2 Planning processes and planning modules. In order to utilize the two production facilities and achieve low-total logistics costs in the entire supply chain, a supply chain network design analysis using Lawson M3 SCP was conducted. The objective of the analysis was to compare the total logistics costs of the following five alternative supply chain set-up scenarios:

(1) *Baseline*. This illustrates the situation before the merge. The Swedish plant can produce everything and supplies the "Swedish" demand in all markets. The Danish plant can produce everything and supplies the "Danish" demand in all markets. No goods flow between plants.

(2) *Focused factory.* In this scenario, the respective production site focuses on unique products. No product is made at both plants. Some production processes are consequently closed in the respective plant. Still, both plants have processes for component and final production. All components used in the final production of a product are not produced at the same production site as the final production. Transportation of components between the sites is allowed.
(3) *Focused market.* In this scenario, the different production sites make all products (i.e. as was done before the merge) but they supply unique markets. The Danish plant supplies the Western Europe and overseas markets while the Swedish plant supplies Eastern Europe and Scandinavia. No goods flow between the plants.
(4) *Segmented supply chain.* In this scenario, the Danish plant is converted into a component producer, supplying the Swedish plant with components for final production. The Danish plant closes processes related to the final production steps, e.g. bulk loading, can filling, fat container filling, box filling and lego production. The Swedish plant closes down some component manufacturing processes and focuses on some other component manufacturing processes and all final production processes. In this scenario, the Danish plant is consequently transferred into a component producer. All components can be transported from Denmark to Sweden but there is no transportation the other way around.
(5) *Focused factory excluding one product group.* This scenario is similar to scenario two, except for final production of one product group that is conducted at both sites. All components can be transported between the production sites.

The planning model used to test the scenarios consisted of three types of nodes; markets, production sites and suppliers. About 49 different market nodes were defined, one for each country. More than 49 different markets existed in reality but small markets were excluded. There were two production sites, one in Sweden and one in Denmark. The production process at each site consisted of processes related to component production and final production. All together, 15 different production processes were defined and used in the model. Four global main suppliers supplied both production facilities with raw materials.

Only bulk transportation using ship was possible from suppliers to production sites. Truck transportation was used for material flows between the plants. Two transportation alternatives were available between production sites and markets: bulk using ship or in pieces using truck. Production capacities were set to equal the present capacity levels at the two plants. Infinite capacities were used for the supply and transportation processes.

Five cost types were included in the model: production, outbound transportation, inbound transportation, inventory and purchase costs. Estimates for transportation, production and purchasing costs were based on actual figures for the Swedish plant. Production and purchasing costs were set equal for the Swedish and Danish plants. Inventory costs were calculated using the present inventory carrying cost percentage of the Swedish company. Six types of raw material were bought from the suppliers. About 1,200 end products were aggregated to about 700 product groups with similar raw material and capacity need. The demand for the 49 markets was based on the actual sales of 2005. No sales price was included in the model. Two six months time buckets were used.

Linear and mixed-integer programming using Lawson M3 SCP was conducted. The objective function was infinite optimization finding minimum total cost. Finite optimization was not used in order to not exclude any possible solution and because one aim of the analysis was to find the low-cost situation, where over-utilization in the present capacities are accepted, and new production investment needs are identified.

4.1.3 Execution and effects. Scenario three, focused market, resulted in the lowest total costs and scenario two the highest costs. The main reason for the higher costs in scenario two is that some of the products moved from Sweden to Denmark are more costly to distribute from Denmark. In scenario three, where all products can be shipped from both production sites, the total logistics costs are minimized. In scenarios four and five, the total logistics costs were slightly higher than the base line. The conduced cost optimization did not consider the fixed and administrative cost effects of closing production processes in Denmark, and costs for IT, organization, etc. The cost effects of closing processes are small in all scenarios except for scenario four where all processes related to final production are closed. These potential cost savings in scenario four are considered to exceed the higher logistics costs compared to lowest cost scenario three in the optimization model. If considering the total annual cost savings of closing these processes, scenario four is, consequently, the optimum scenario with the lowest total costs.

The supply chain design analysis at AAK was only conducted at one time. The aim was to use the results as input to the supply chain design decisions after the merger. However, the ambition when setting up the model was to be able to use it also on a continuous basis for master planning on a tactical level. This has not been the case.

One person worked full time for about a month to gather and register data for the model. Most data was exported from the ERP system, manually adjusted, imported and typed into Lawson M3 SCP. A materials planner, a distribution planner, two software consultants and the supply chain manager at Karlshamns AB together spent a total of two months of full-time work on designing and running the model. The total time for data gathering and designing and running the model was consequently about three full-time working months.

No formal planning organization was set-up for the analysis but the results were used as input to the supply chain design discussion between the two previous firms. The fact that one of the original organizations was responsible for developing the model decreased the commitment to and use of its results. The other organization did not feel commitment to the results in the same way as the one that developed the model.

4.2 Case II – Svenska Lantmännen

4.2.1 Company characteristics and planning problem. Svenska Lantmännen (SL) (The Swedish Farmers Supply and Crop Marketing Association) is one of the leading groups within the grocery and agriculture industry in Sweden. It is a producer cooperative that works together in marketing, distribution, sales, processing and supply. Large profit margins are not the goal so much as cost reduction through the entire chain. This is due to that the owners, some 50,000 Swedish farmers, are both suppliers and customers to the central production and distribution function. The core business has some 1,500 employees in 13 geographically separate areas in Sweden and supplies its customers with seed, fertilizers and feed among other things, and of course process and sells what the farmers produce. Prior to 2001 the farmers acted in local and regional cooperatives but in 2001, SL was founded out of merging these cooperatives. Since, then the group has suffered from inefficiency and surplus capacity. Several structural changes and reorganizations have been carried out in order to streamline the business. In 2004, a major restructuring of the seed supply chain was undertaken. Two out of six production plants was shut down and two out of four central warehouses were closed. Restructuring the seed supply chain resulted in less capacity in both production and warehouses.

Recently, every plant supplies a restricted number of customers within the nearest geographical regions. Only in a few cases the production is differentiated between the plants. The main distribution strategy is to ship finished products directly from the finished products inventory at the plants. This leads to a large number of distribution relations that put pressure on transportation efficiency. The seed product group contains about 270 different SKUs that show a typical 80/20-volume ratio. The final products are sold in discrete entities in form of 20 to 700 kilogram bags and the raw material is supplied as bulk. The demand for seed is highly seasonal, and about 70 percent of the volume is sold during a period between December and March. The large volumes and the many suppliers and customers make the business dependent on efficient inventory and distribution management. The planning process is difficult due to the high-seasonal fluctuations and the fact that seasonal stock can only be built up in restricted amount.

4.2.2 Planning processes and planning modules. The restructuring of the supply chain was complemented by changes in the mid-term supply chain master planning in form of a new centralized planning function. Earlier the mid-term planning (including production and distribution) had been carried out locally/regionally. In addition, the new centralized planning function was in need of computing decision support in order to find feasible plans for the entire supply chain. The logistics division investigated the use of decision support through APS in a feasibility study in mid 2004. Two months later the mid-term supply chain master planning APS module Lawson M3 SCP was implemented and in use.

The tactical planning process and related APS modules are shown in Figure 2. Sales forecasts are conducted by the marketing and sales function and are mainly dependent on historical sales data. To be able to meet the high seasonal demand peaks surplus capacity is needed in the supply chain. Furthermore, the access to raw material is in great extent dependent on weather and other factors that are hard to predict.

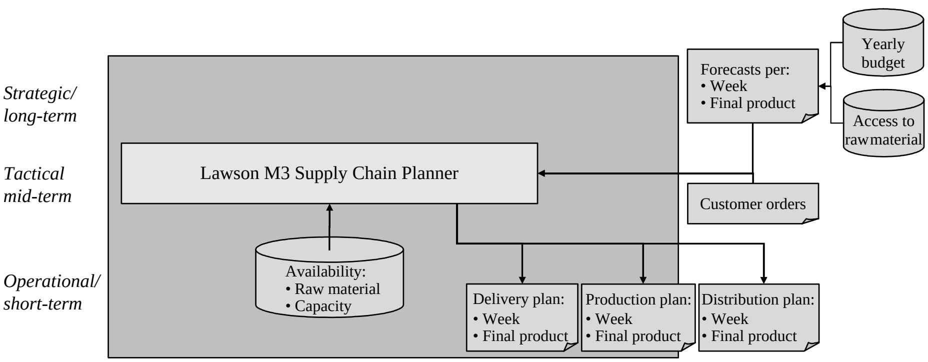

Figure 2.
SL's tactical planning process and related APS modules

Planning with M3 SCP balances supply and demand for each weekly time bucket during the planning horizon (the remaining season). Forecasts are based on the yearly budgeting process and only updated twice a year. Production and inventory levels are matched with capacity for each period to minimize total supply chain costs. The planning process with M3 SCP is done in an iterative manner where bottlenecks are identified and handled by the planner. Data are extracted from the company's ERP system and used by the M3 SCP module. The solver engine uses linear and mixed-integer programming to solve the planning problem with respect to total cost minimization. Short-term production scheduling as well as planning supply is carried out locally at the plants according to the directions given by the aggregated master plan. Transport planning (routing, loading, etc.) is outsourced to a third party that executes the deliveries within the frames of the distribution plan.

4.2.3 Execution and effects. In a study carried out in 2005 (Andersson, 2005), the effects on total costs regarding the seed production and distribution at SL was evaluated. At the same time, the flow of goods and the implementation of the APS at the centralized master planning function were investigated. The results show that the structural changes and the implementation of the APS have streamlined the production and distribution network regarding the flow of goods. Total costs have decreased by some 13 percent on a yearly basis, while at the same time the quantity of sold units has increased. This results in a total reduction of cost by some 15 percent per tonne. Furthermore, inventory levels in production facilities and warehouses were reduced by almost 50 percent, and inventory reductions were realized for raw material, WIP and finished products.

The SCP trade-off have had the following consequences: in general increased production batch sizes, slightly higher transportation costs due to lower fill-rates, decreased production cost and less capital tied up in inventory because of better throughput. The reinvented SCP has reduced the total planning time. Central planning has increased the control of material flows in the chain as well as the cost structure. A higher understanding of the supply chain trade-off makes further development of immediate importance. Optimizing the supply chain has not been the most important objective with the APS implementation. The main focus has been to gain acceptance for the central master planning function and enable communications between functions. Acceptance for this APS in the rest of the organization made it possible to consider further APS implementations. More structural changes through rationalization and more products will in the future go under central APS planning. In addition to the monetary gains by the restructuring, the new way of planning increased the communication between logistics, manufacturing, marketing and sales functions.

4.3 Case III – SSAB Oxelösund

4.3.1 Company characteristics and planning problem. SSAB Oxelösund (SSAB) is a member of the SSAB Svenskt Stål AB Group and is the biggest Nordic manufacturer of heavy steel plates. The company is also a world leader in the specialist field of quenched and tempered steels, with brand names such as HARDOX and WELDOX. SSAB, with an integrated process extending from iron raw material to finished plate, produces around 632,000 tonnes of heavy plate (2005) of which 90 percent are exported. Germany is the biggest single export market, but SSAB carries finished goods inventory in more than 40 countries around the world. At the end of the fiscal year 2005 SSAB had sales of SEK 9.2 billion and a yearly profit of 2 billion, with close to 2,500 employees.

Traditionally SSAB's tactical master planning process was made up of a series of disintegrated and manual procedures aided by various spreadsheets and small local databases. Considering the large number of regional sales managers (close to 100 at the time), the large numbers of SKUs, the company's global spread and the fact that the company strives for the high-end, high-profit market (which includes customers with high demands), the planning situation became untenable. Customer service, and especially on-time-deliveries, is considered to be the order winner, but the manual planning procedures resulted in poor performance on this important criterion. Furthermore, the demand for SSAB's products is higher than what the present production facility can produce. In that sense, it also becomes important to prioritize among customer orders in order to satisfy the most important customers and to maximize profits. Within the existing planning processes, some resources were over-utilized and others under-utilized. The acceptance of the sales forecasts in production was low and the trust among the market and sales force in the production capacity was low, i.e. there was often a misunderstanding between production, marketing and sales.

4.3.2 Planning processes and planning modules. In 2001, SSAB initiated a project to streamline its tactical planning and to find suitable DSSs to achieve an effective master planning for the entire company. After a thorough selection process SSAB choose to implement a product suite from i2 Technologies to address the planning problems. In 2002 i2's Demand Planner (i2 DP), Supply Chain Planner (i2 SCP) and Demand Fulfillment (i2 DF) was up and running. The tactical planning process and the related APS modules are shown in Figure 3.

The tactical master planning process starts with forecasts produced by some 100 regional sales managers that are entered into i2 DP. The forecasts are thereafter consolidated and transported into the i2 SCP. The forecasts used to feed the i2 DP and i2 SCP are based on three dimensions; geography, product, and time. The geography dimension describes SSAB's sales organization and it goes all way down to consignee. SSAB's market consists of some 1,000 major customers that are divided into approximately 100 sales regions, each managed by a regional sales manager. The regional sales managers are responsible for providing forecasts on a rolling 18 months time horizon, of which the first six months should have "high" forecast accuracy. Each forecast includes data on sales volume per customer (in tonnes) and also sales price for

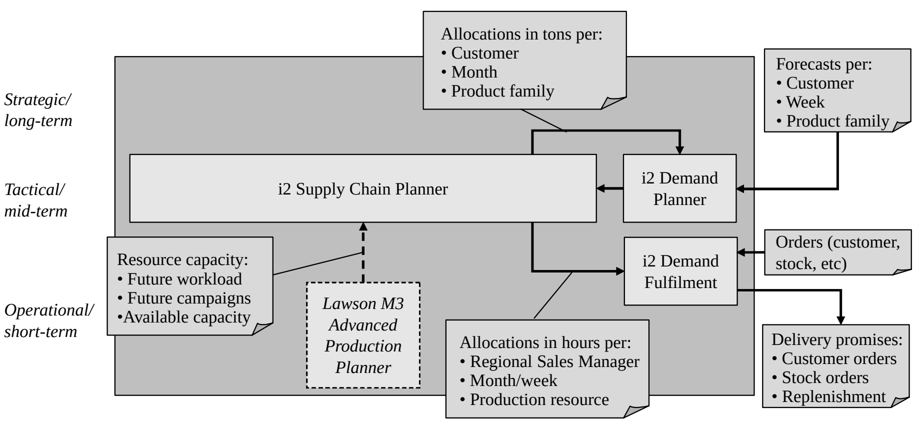

Figure 3.
SSAB's master planning process and related APS modules

each product group in monthly time buckets. In total SSAB has around 250 different product groups and the sales manager typically carries 20 customers in his account. Hence, there are a lot of forecasts that have to be consolidated in the demand planner before the data is exported to i2 SCP.

The aggregated forecast from i2 DP is imported into the i2 SCP where the forecasts are matched to the available capacity based on a set of priorities and business rules. The forecasts are disaggregated from monthly to weekly buckets for the first 12 weeks and the basic capacity data used in the SCP optimization is imported from the Lawson M3 APP system. The demands put upon SSAB are much larger than the available capacity, wherefore the aim of the SCP optimization is to match the forecasted demand with the available capacity based on profit maximization and a pre-defined set of business rules. The results of this process are then exported back to the i2 DP in tonnes to direct the sales manager in terms of resource allocation, and to the i2 DF in terms of available capacity in hours per priority group to quote delivery promises on a short-term basis.

i2 DF is the unit that keeps track of the allocated hours per sales region and makes the customer order promises, based on an available/capable-to-promise calculation. When an order is entered into SSAB's Order Entry System the requested delivery time and volume is checked in i2 DF and if capacity is available within the inquired lead time, a delivery promise is returned. In order to handle the fluctuations in sales that always occur, SSAB has the possibility to use business rules built into the system. These rules are set up individually for each business area. When the system cannot find capacity within own allocation the system starts looking elsewhere until capacity can be found.

4.3.3 Execution and effects. The key goals of implementing the i2 suite were to handle the excess demand (scarce capacity) and to improve delivery performance. The capacity problem is temporarily solved through the use of finite master scheduling aiming at maximizing profits by using available capacities, after prioritized orders are scheduled, for the most profitable orders. As such less profitable orders are rejected to cope with the limited capacity. In the long term SSAB is shopping for more capacity, both internally and externally. Looking at the delivery reliability since the APS modules were implemented, it is not obvious that the goal is fulfilled. The delivery performance has, on average, been kept at a fairly stable and slowly increasing level. However, since the time of the implementation demand has increased heavily and SSAB has suffered from two severe breakdowns. Normalizing data from these effects (increased order stock and breakdowns) it is clear that the APS suite has had positive effects on delivery performance. Besides, the communication and confidence between marketing and production has increased through the increased visibility of demand and delivery promises. Another consequence of the APS implementation is that the process and demand uncertainties have decreased and as a result of that, the inventory levels have been reduced (however, also affected by the increased demand).

5. Analysis and conclusion

Here, the three cases are compared in order to explore why and how APS was used and what it resulted in. Table I contains a summary of the case characteristics. All three cases used SCP optimization software for planning on strategic and tactical levels. However, AAKs used it to generate decision support for cost efficient supply chain design. This planning was only conducted at one single time, when merging two companies.

Table I. Summary of case characteristics

Issue	AArhusKarlshamn	Svenska Lantmännen	SSAB Oxelösund
Demographics	Manufacturing oils and fats. Merger, between a Swedish and a Danish plant. Global customers and suppliers	Producer cooperative. Swedish farmers are supplier/customer and own the cooperation	Biggest Nordic manufacturer of heavy steel plates. Integrated processes. Customer worldwide, subsidiary in 40 countries
Physical supply chain structure	Few suppliers, two production facilities with multiple capacity units and finished products in several markets	Some 50,000 farmers that are both suppliers and customers to five production sites and four distribution centres	Infinite supply, one production facility with multiple capacity units and finished products in multiple markets
Planning level	Strategic supply chain design	Constraint-based master production scheduling with a focus on distribution and transportation	Constraint-based master production scheduling and capable-to-promise calculation
Planning problem	How to utilize two identical production sites in the most cost efficient way	Inefficiency and overcapacity	Capacity shortage and utilization. On-time-deliveries not reached
Software	Lawson M3 SCP	Lawson M3 SCP	i2 SCP, DP, DF
Model design	Cost optimization. Infinite capacity	Cost optimization. Finite capacity	Profit optimization. Finite capacity
Planning data	Manually from ERP	Imported from ERP and Excel spreadsheets	Imported from ERP, through own data base
Planning organization	One person gathers data, one material planner, one distribution planner, two consultants and one SCP	One central master planner and local requirements planners at each site that works in accordance to the central plan	Salesmen register individual forecasts and makes delivery promises. Three master planners responsible for the process
Planning effects	Found the scenario of lowest cost. The total cost of the optimum scenario lower than the base line scenario. Not everyone was committed to the result	Reduced total costs and inventory levels. Increased communication and control. Lower fill rates and higher transportation costs	Increased delivery performance and communication in the supply chain. Balanced capacity utilization and decreased inventory levels

SL and SSAB used it for continuous master production scheduling in situations with finite capacity constraints. The planning problems are, consequently, quite similar for SL and SSAB but different for AAK. In all three cases, the overall aim of using APS was to create holistic perspectives of complex planning problems, eliminate sub-optimization and achieve commitment to an "optimum" plan.

5.1 Planning complexity

The planning situations in all three cases can be characterized as being complex. The type of complexity differs, however, between the companies. For AAK, the planning complexity was caused by a large number of variables related to the physical supply chain structure (e.g. multiple production sites, production processes, products, markets) to include in a total cost calculation. For SL and SSAB the complexity was caused not only by both a large number of physical supply chain structure variables but also to multiple business constraints and decision rules, affecting the feasibility of the master plan. This was especially true for SSAB. The high levels of complexity were the main reason for all companies to implement APS in the first time. The complexity levels of all cases were considered too high to solve without APS.

5.2 Planning model and design

When the planning problem complexities increase, the complexity of the optimization conducted in the planning model also increases. The optimization complexities differed between the cases. AAK conducted cost optimization using infinite capacity while SL and SSAB used cost and profit optimization with fixed product price, respectively, using finite capacity. Finite planning puts higher requirements on up-dated work centre data, compared to infinite planning. This should be especially critical on more detailed planning levels when working with short time buckets, which was not the case in the studied cases. Profit optimization requires sales data in monetary figures. SSAB had the highest optimization complexity of the three studied cases, not only because of its use of profit optimization and finite capacity in several capacity units but also because of the high decision making complexity they wanted to consider in the planning model. This may have affected the acceptance of and commitment to the plans. Most identified references describing successful APS implementations (Brown *et al.*, 2001; Gupta *et al.*, 2002) are based on non-standardized software. The possibility of solving the actual planning problems depends on the type of APS system used. In standardized APS it may be impossible to model the actual complexity and solve the resulting optimization model in a realistic way. The necessary assumptions and simplification of the problem, for example, regarding capacities and economies of scale, may in some situations have great impact on the usefulness of the output. At AAK and SSAB, several simplifications were necessary in order to use standardized APS. Still, the perception was that the output was good enough.

5.3 Planning data

The gathering and registering of basic data was not considered to be problematic in any of the cases. Gathering and registering basic data in a cost efficient way and resulting in availability of high-quality planning information should be more critical when working with close to real time data in finite planning models with short planning buckets and high-planning frequency (APICS, 2007). The capable-to-promise calculation in the SSAB case was the only planning process working in real time with customer orders. All the other planning processes worked with longer time horizons, driven mainly by forecast data. In the AAK case, where the optimization was carried out only at one time, all data registration was, however, conducted manually. If running the model a second time, several of the manual activities could be eliminated. Consequently, the data gathering and registration processes were not critical in the present planning environments, characterized of vertically integrated supply chains consisting of one or multiple sites and the basic data possible to up-load from a common ERP system.

5.4 Planning organization

For all three cases, several organizational units were involved and affected by the planning process. Thus, an important aim was also to create commitment to an "optimum and feasible" plan through out the organization. For AAK the cost optimized output was considered the most important output of the planning but for SL and SSAB, using APS in the master planning processes, it was almost more important to generate commitment to one single plan through out the organization rather than finding the optimum plan. Still, the cost and profit optimizations were considered important for SL and SSAB and commitment very important for AAK. In all cases, one business unit was formally responsible for setting-up and running the APS-based planning. In the AAK case, other business units that were affected by the planning output were not involved during any phase of the planning. This resulted in existence of parallel plans and very low commitment to all generated plans. In SL and SSAB, the responsible business units acted as centralized planning functions. They worked actively with the involved parts (sales, production, etc.), with planning meetings but also with education and training. This was especially the case at SSAB. Still, no true collaborative planning, as outlined in, for example, the CPFR or Sales and Operations Planning concepts (Stadtler and Kilger, 2005) was conducted. The planning was the "show" of only a few people. The lack of involvement of the other functions and processes may have had negative impact of the planning performances and commitment to the generated plans. This was, however, not studied here.

5.5 Planning effects

The perceived effects of APS cannot be analyzed in isolation from the context where it is used, for example, the design and function of the planning organization. An appropriate planning organization is most likely necessary for utilizing the potential of the APS, and the commitment to the plan generated by the APS. APS usage could also improve the acceptance and trust in a centralized planning organization as such, resulting in common priorities and commitment to single plans. The relationships between planning organization, APS usage and performance effects were not analyzed in detail in this study. However, some observations were made. In the AAK case, optimization results indicate that the performance effects could be significant but the lack of involvement in the process and commitment to the results reduce the real performance effects. In the SL case, the APS implementation was conducted together with a structural change in the planning processes and centralization of the planning organization. All changes should impact the commitment to a centrally generated plan and the operative planning performance in positive ways. In the SSAB case, the APS usage was also supported by a centralized planning function, however, belonging to the marketing function, which was one of the functions to be coordinated in the centralized planning process. In none of the cases a centralized planning organization was set up in order to monitor critical path of the supply chain, conduct what-if analysis, event-based re-planning, etc. The ambitions were to manage the steady-state master production scheduling processes.

6. Concluding remarks and further research

APS are identified as potential support tools for managing complex SCP problems and as means for supply chain integration. This paper fills some of the knowledge gaps about how this could be done and the perceived effects of using APS, focusing on the strategic and tactical planning levels. Three explorative case studies show how APS can enhance SCM in various situations. Noteworthy is that all three cases are centred on the software use of a so-called SCP module, but the module is used on different planning levels addressing different problems. One of the cases uses the SCP as a SND tool. The two reminding cases use it as a tactical master planning tool, one in a single site setting and one in a multi-site setting including both production and distribution issues. Hence, the SCP module as such must be considered fairly general indicating a wide area of application for tactical APS modules. Similar findings have been reported in literature. Brown *et al.* (2001), for example, show how Kellogg's uses the same module for both SND and for MMP. This further highlights that companies must treat APS with caution and put a lot of effort into the four issues of planning complexity, model design, suitable planning data and a proper planning organization. In our cases, SCP software, based on linear and mixed integer programming, could support a cost optimized SND in a merger of two companies, production and volume allocation in one case, and how efficiency, capacity utilization and delivery service problems were considered and decreased in two cases. These latter two cases also showed how APS can support the integration between the marketing and production functions and the commitment to a common plan throughout the supply chain. The relationships between APS, planning organization and planning effects are thus obvious in these cases.

Several positive effects of using APS as support for global SCP on strategic and tactical levels were identified, but the research conducted here also identifies and motivates several future research areas about the appropriateness and performance of APS usage. Based on the areas described in the last section of the frame of references and explored in the case analysis, several different research issues related to the following areas can be motivated:

- the feasibility of APS in situations with various planning complexities;
- how design of the optimization model create complexity and affects the planning process;
- data gathering requirements when using APS;
- the role and design of the planning organization; and
- how to achieve positive planning effects, such as finding the global optimum of plans, global commitment to the same plan and developing supply chain process integration.

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Paper II

The potential benefits of advanced planning and scheduling systems in sales and operations planning

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Abstract

Purpose: The purpose is to explore what potential benefits may be achieved by using APS systems in the S&OP process.

Design/methodology/approach: Several methods have been used; literature review, Delphi study, and a case study at a company in the chemical industry which uses APS system support in the S&OP process.

Findings: Three types of potential benefits were found to be achieved when using APS in the S&OP process; benefits concerning decision support, planning efficiency and learning effects. The most common type was decision support benefits according to APS users and APS experts. The results from the case company showed that the benefits perceived in the different S&OP activities differed. In the activities concerning the preparation and generation of delivery plans, the perceived benefits mainly concerned learning effects. In the activities concerning the generation of a production plan, the benefits were foremost found in planning efficiency. In the S&OP meeting decision support benefits were highest valued. The reason for the different results can be explained by the aim of the activity, how APS was used in the activity, the user characteristics and the design of the model and access and quality of planning data.

Research limitation/implication: Benefits can be captured at different levels. They can mean different things to different people. The type of data can also be either objective or perceptual. This study investigates benefits at the S&OP process level by interviewing APS experts and APS users.

Practical implication: The findings about the types of APS potential will assist companies in understanding the benefits they can expect from its use in the S&OP process. The case study analysis gives further insight into how APS can be employed and what benefits different APS user categories can expect when it is used in an appropriate way.

Originality/value: The knowledge about which benefits that can be achieved when using APS in the S&OP process is quite unexplored. This paper fills some of these gaps.

Keywords: Sales and Operation Planning (S&OP), Advanced Planning and Scheduling (APS) systems, decision support, planning efficiency, learning effects

Paper type: Research paper

1. Introduction

Sales and operations planning (S&OP) is supposed to create a long-term balance between demand and supply by focusing on the right volumes to supply and sell (Olhager et al, 2001). An overall aim is to create consensus among several functions and actors, and to settle around one set of plans (Feng et al, 2008). Many benefits related to business performance can be associated with this process if managed in an appropriate way, e.g. by improved customer service, lower inventories, shorted customer lead times, and stabilize production rates (e.g. Wallace, 2004). However, the S&OP process can be quite difficult to handle without any software system support. Which is why many companies have started to demand advanced system functionalities (Straube, 2006).

Advanced Planning and Scheduling (APS) systems normally include demand, supply and/or specific S&OP modules with the functionality needed for supporting the S&OP process. These systems should consequently be appropriate to apply as S&OP support (Stadtler and Kilger, 2005). However, few studies have been made on how APS is used in practice (Wiers, 2001) and the benefits in which an APS approach results (Lin et al, 2007). Instead, most research concerning APS has focused on designing advanced algorithms to solve planning and scheduling problems (Lin et al, 2007). The few studies made on how APS is used are of a descriptive nature, where benefits generated from the APS use are only of indirect interest. Besides, most studies describe how APS supports the planning in general and do not look at a specific planning process.

Provided that the APS system is successfully adopted and implemented, there is great potential to receive value of the APS investment (Stadter and Kilger, 2005). Still, if the APS system is not used it does not matter how well it was selected or implemented. The S&OP process is made up of several activities. Some examples are the generation of a final delivery plan, and the preparation of a preliminary production plan with several aims involving different actors and planning tasks (Feng et al, 2008). It is therefore reasonable to believe that APS is used differently in these activities and that the benefits one receives in one process differ from the other.

From an academically point of view, it would be interesting to fill the gap regarding APS benefits as it is important to understand what the APS approach really results in, considering the great amount of effort put into developing advanced planning and scheduling algorithms. Most of the information system (IS) literature also focuses on the adoption and implementation of information systems (Zhu and Kraemer, 2005; Häkkinen and Hilmola, 2008) and there is a need for better understanding how the IS usage influences the benefits achieved. The potential value of knowing the APS benefits is important also for practitioners. Senior executives could for example use it as one of several tools to assess whether the potential benefits of APS support overall business objectives. Thereby they will be able to approve or reject APS implementations. Alternatively, it could be employed in the post-implementation phase as an evaluation mechanism to assess whether anticipated benefits were realized.

This study aims to fill some of the above mentioned gaps. The purpose of this paper is consequently to explore the potential benefits that will be achieved by using the APS system in the S&OP process. The study aims, in particular, to structure the different types of benefits that have been reported in the literature, and to enlarge the list with experiences from practice. The study also aims to find out if the benefits perceived are different in the S&OP activities and how the use of APS influences the benefits perceived. The remainder of this paper is organized as follows: The first chapter about methodology, describes the research design and the assumptions made. Thereafter an analytical framework is built up with the help of previous literature on production management and information systems. The case company and the use of APS in the S&OP processes are thereafter described and the results from a questionnaire and interviews with APS users are presented. The analysis and discussion are integrated in one chapter. The paper ends with a conclusion, limitations and future research.

2. Methodology

When investigating in what benefits the use of an information system can result, there are several questions to be asked: What qualifies as a benefit? Benefits for whom? Unit of observation? (DeLone and McLean, 2003). In accordance with Chau et al (2007) we defined benefit as the consequences of system use. In the IS effectiveness literature, the consequence of use can be measured at different levels such as individual, group, organization, society (Miriani and Lederer, 1988). In this paper, we are studying the benefit for the S&OP process (Figure 1). As illustrated in Figure 1, we are not only interested in what benefits the APS usage gives the S&OP process as a whole, but also what benefits APS usage gives each activity in the S&OP process. Both focuses are taken in the analyses.

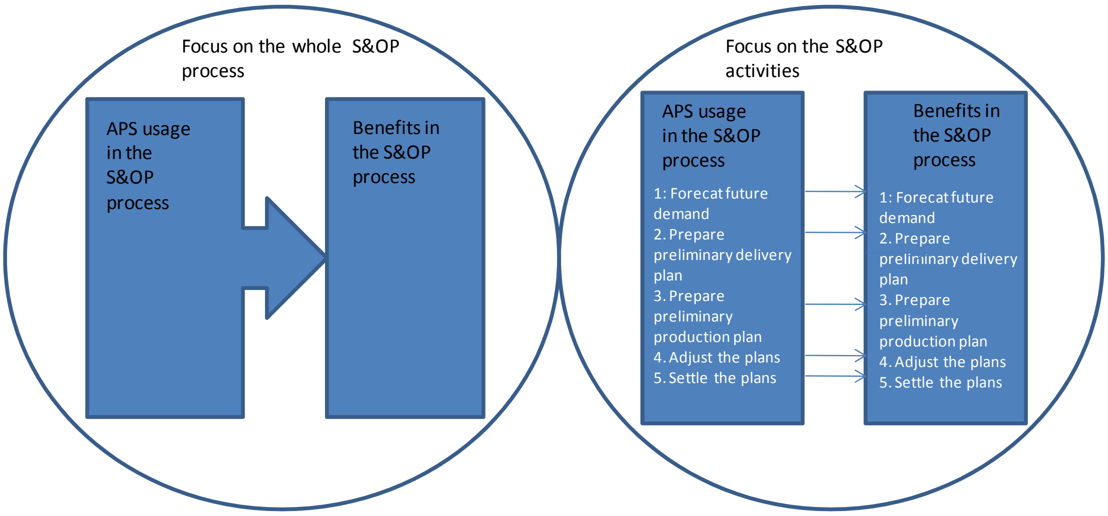

Figure 1: The unit of analysis – two focuses.

In order to pick up the potential benefits and understand how the APS usage influences the perceived benefits, we used several different data collection methods such as literature reviews and a Delphi study among APS experts. We also interviewed and conducted a survey among APS users at a case company. Figure 2 presents a research design consisting of six phases. The first phase concerns the literature study. Phases 2-4 concern the Delphi study. Phases 5-6 concern the case study. The different phases are described below.

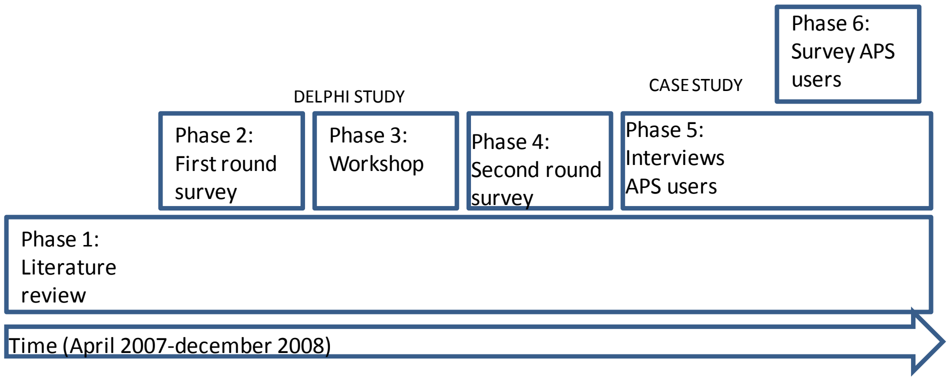

Figure 2: The research design phases

2.1 Literature study (Phase 1)

A literature review was conducted in order to describe the state-of-the-art understanding of how APS provides benefits to the S&OP process. As there is not much written about APS system in production, logistics and operation management, the review was complemented with literature on information systems.

2.2 Delphi study (Phases 2-4)

A list consisting of five potential benefits was developed with the help of the literature and previous knowledge we had from conducting case studies at companies using APS systems. The list was tested in a Delphi type of study, with independent experts in order to validate single case findings and improve the generality of the findings. Fifteen industry and consulting representatives with experience from APS implementation and usage were selected and included in our study group. They were asked to identify additional benefits of the list and rank the extent to which they perceived that APS usage results in the respective potential benefit, on a seven point scale (ranging from very badly to very well) (phase 2). The mean of the rankings and a revised list, consisting of nine potential benefits, were thereafter presented for the fifteen experts in a workshop. During the workshop, the list was discussed and adjusted and a new list with eleven potential benefits based on the results from the workshop was developed (phase 3). As all potential benefits were ranked high, the workshop participants were asked to mark the three potential benefits that APS foremost generates (phase 4). The results of this second round survey are presented in Appendix A. The results were discussed with the expert group, who considered them to represent relevant consensus rankings of the potential benefits. No further questionnaire round with the expert group was therefore considered necessary.

2.3 Case study

Case study research is considered preferable when the experience is rare and the contextual conditions are unknown (Voss et al, 2002), It is also a preferred method when "how" and "why" questions are addressed concerning contemporary set of events over which the researcher has little control (Yin, 1991). We wanted to explore how the APS usage influenced the perceived benefits in the different activities, which is why case study was considered the most appropriate research method. The case firm, a company in the chemical industry, was selected as it had a long and wide experience of using APS systems to support its S&OP process. APS was implemented to support the coordination of material flows and to keep away from sub-optimizations in an environment characterized by complex planning tasks. Since some of the main features of APS is to coordinate and integrate certain entities and produce feasible near optimal plans (Stadtler and Kilger, 2005) and it is argued that APS is an appropriate tool for supporting complex tasks environments (Setia et al, 2008), the use of APS in the case company was considered suitable. The APS system was well implemented and integrated with the existing organization and IT structure, and the APS users worked daily with the modules. It was therefore considered that the use of APS at the case company brought many benefits to the users.

In-depth interviews were carried out with over twenty people involved in the S&OP process and lasted about 90 minutes each (phase five). The interviewed personnel were either direct users (working with the APS modules) or indirect users (using the output from the APS modules). They were asked about the consequences the use of APS system in the S&OP process has resulted in, and what factors that are important to consider for successful usage. In order to improve the reliability and validity, research protocols were designed and used in the interviews (Voss, 2002). The protocols were tested in initial interviews with key respondents. Respondents were frequently asked the same questions to enhance the reliability of the data and some informants were interviewed several times. The notes from the interviews were sent to the interviewees for feedback and checking of the data.

In order to find out if there were any differences in perceived benefits among the S&OP activities, a questionnaire was developed based on the literature and the Delphi study (phase six). This questionnaire was modified in two ways: some words in the list were changed to fit the case company and some benefits were split into multiple benefits in order to be more detailed and not measure multiple issues. Before the questionnaire was sent to the respondents it was sent to three co-workers at the researchers' department for feedback. This resulted in some adjustments to the questionnaire. The final questionnaire consisting of eighteen benefits (Appendix B) was sent to all 63 actors involved in the S&OP process, out of which 28 answered the questionnaire. The respondents were asked to rate how well the listed benefits correspond to their perception of using APS in the S&OP process on a seven point scale. It is worth noting that since the number of respondents was small no significant statistical analysis was possible to conduct in order to analyze the answers. Instead the results from the questionnaire were only used to identify tendencies of the benefits perceived in the S&OP activities. Even though the response rate in the questionnaire only reached 44%, there are enough answers to give some indications about the tendencies concerning the benefits perceived. The people that answered the questionnaire are central actors in the S&OP process and the questionnaire was conducted in parallel with interviews.

3. **Theoretical framework**

In the following section a description of how S&OP is conducted is given and the APS modules supporting the S&OP process is presented. Thereafter, potential benefits of using APS in planning processes and antecedents to benefits are described. The section ends by summing up the results in a table.

3.1 Sales and operations planning

S&OP is normally a monthly based tactical planning process performed to balance demand and all supply capabilities in order to ensure that the plans of all business functions are aligned to support the business strategic plan (Fen et al, 2008). Based on Wallace (2006), Grimson and Pyke (2007), and Jonsson and Mattsson (2009) we emphasize five main activities in the S&OP process;

- Activity 1: normally the sales and marketing department produces a forecast of the coming planning period's expected demand. This type of forecast refers to product groups and extends over a relatively long time in the future, at least corresponding to a full budget cycle.
- Activity 2: the sales and marketing department prepares a preliminary plan for future sales and delivery volumes (demand plan). Previous sales and delivery plans should be compared with volumes actually delivered. Goals are also established for inventory size or order backlog.
- Activity 3: the production departments and those departments responsible for the procurement of start-up materials for manufacturing, will prepare preliminary production plans (supply plans). These production plans relate to volumes to be produced and delivered from production for each period during the planning horizon.
- Activity 4: involves a reconciliation meeting between the managers of the company's marketing, production, procurement, financial and logistics departments. When consensus has been reached, a proposal is established. Thereafter a recommendation is made for a final delivery plan and production plan for the coming planning periods.
- Activity 5: the proposal for a delivery plan and production plan, including any other preliminary decisions taken as a result of plans drawn up, is put forward to the company's top management group. Any remaining unresolved issues are considered. When an agreement has been reached, the members of the management group meeting will settle the delivery plan and the production plan.

3.2 Advanced planning and scheduling (APS) system

According to APICS (2007) APS is included in the group supply chain management (SCM) software and is defined as: *"any computer program that uses advanced mathematical algorithms or logic to perform optimization or simulation on finite capacity scheduling, sourcing, capital planning, resource planning, forecasting, demand management, and others. These techniques simultaneously consider a range of constraints and business rules to provide real-time planning and scheduling, decision support, available-to-promise, and capable-to-promise capabilities"*.

APS systems are either add-ons or direct integral components of ERP systems, which create the support mechanism for planning and decision-making at the strategic, tactical and operational planning level (Lin et al, 2007). One way to classify APS systems is by categorizing different modules depending on the length of the planning horizon on one end, and the supply chain process that the module supports on the other (Stadtler and Kilger, 2005). This paper focuses on S&OP, which relates to the tactical planning level where the multi-site master planning and demand planning should be of interest.

The demand planning module is used to support a market demand forecasting by using different forecasting methods. A common feature of APS demand planning tools is the possibility to integrate different departments/companies into the forecasting process, and to aggregate/disaggregate forecasts according to pyramid forecasting (Kreipl and Dickersbach, 2008). The multi-site master planning module[1] aims at synchronizing the flow of materials along the supply chain, and thereby balancing demand and capacity. It supports the mid-term decisions concerning efficient utilization of production, distribution and supply capabilities (Stadtler and Kilger, 2005). The multi-site master planning module not only balances demand with available capacities but also assigns demands (production and distribution amounts) to sites in order to avoid bottlenecks, wherefore it has to cover one full seasonal cycle, or at least 12 months in terms of weekly or monthly time buckets. Owing to the complexity and detail required in the model, only constrained (or near-constrained) resources are modeled in detail. To increase the solvability of the model, most vendors distinguish between hard and soft constraints in the linear programming (LP) or mixed integer programming (MIP) model that is used (Entrup, 2005). While hard constraints have to be fulfilled, the violation of soft constraints only renders a penalty in the objective function.

3.3 Potential benefits of using APS

The literature reports some benefits of using APS systems in planning processes. Brown et al. (2001) present a large-scale linear programming optimization model used at Kellogg’s to support production and distribution decision-making at operational and tactical levels. The use of the model developed in-house at Kellogg’s has resulted in better decision-making and overall cost savings. Gupta et al. (2002) describe a decision support system that helps Pfizer plan its distribution network, with the model useful in strategic, tactical, and operational planning situations. The use of the decision support system has generated many benefits: improved transportation-scheduling support has led to savings in freight costs, elimination of customer deductions has amounted to several thousand dollars annually, and a strategic manufacturing plan has saved millions of dollars each year. However, the greatest benefits identified were the intangible ones: it helped managers to understand the cost and service implications of proposed network alternatives and raised people’s awareness of and ability to act on supply chain issues. It also enhanced the firm’s ability to remediate supply chain problems, resulted in proactive improvements, and increased people’s confidence in the planning.

Dehning et al (2006) examines the financial benefits of IT-based supply chain management systems. They suggest that SCM systems add value to the inbound logistics through the availability of more current and accurate information regarding orders that is shared with suppliers. In addition SCM systems support operation processes by coordinating marketing forecasts, production schedules

[1] Notice that there are other names for this module, e.g. supply network planner, supply planner and supply chain planner.

and inbound logistics. They also increase the firm´s ability to adapt to unplanned events. As a consequence, inventory levels and costs can be reduced and higher capacity utilization achieved. Fleischmann et al. (2006) explain the modeling of a decision support system used at BMW to support tactical and strategic planning. The model made the planning process more transparent and was accepted by the many departments concerned, which provided the necessary data. The model reduced the planning effort and allowed planners to investigate various scenarios more frequently than they could in the past.

All in all, it greatly improved the decision support for BMW's overall planning. Jonsson et al. (2007) explored how APS systems can be used to solve planning problems at tactical and strategic levels, and the perceived effects of using APS systems. The perceived effects reported from the three case studies examined were: total cost reduction, decreased production cost and less capital tied up in inventory, and positive effects on delivery performance. A reduction in overall planning time was also identified and the planning organization increased the control of material flow and cost structure. Further, the visibility of demand and delivery promises increased and the process and demand uncertainties decreased. A greater understanding of supply-chain trade-offs and further developments of immediate importance were also found. Setia et al (2008) developed a framework for organizational value creation from agile IT applications where APS systems were used as example. It was found that the APS facilitated the demand allocation process. It also provided divisional capability for instantaneous order commitment and timely communication with other organizational IT applications.

3.4 *Antecedents to benefits*

The benefit one receives in the end is influenced by a number of factors and a large number of studies have been conducted with the aim of explaining the antecedents of information system effectiveness (Zhang et al, 2005). In general, the results of the studies have been mixed due to the many factors that may cloud the relationships between benefits and its causes (Grover et al, 1996).

Recent evidence suggests that IT investments such as APS systems are most likely to provide benefits when well targeted, well timed, well managed and accompanied with complementary investments and actions (Dehning et al, 2006; Setia et al, 2008). The characteristics of the information system implemented also seem to influence the benefits one receives from using the system. Schroeder et al (1981) identified the MRP type (computerization, accuracy of data) as an important independent variable for MRP success. Similar findings have been identified in APS studies. Zoryk-Schalla et al. (2004) e.g. stress that a key success factor for implementation of an APS system concerns consistent modeling. Wiers (2002) and Stadtler and Kilger (2005) highlight the importance of a strong integration with the APS system and the existing IT infrastructure as well as a strong coordination of APS modules. Jonsson et al (2007) and APICS (2007) emphasize the need for access to planning data and insistence that planning data are up-dated and accurate. The user acceptance is another factor that is of great importance for system success. According to Torkzadeh and Dwyer (1993) most information system failures result from a lack of user acceptance rather than poor quality of the system. Amoako-Gyampah (2004) stresses that user acceptance is not only influenced by variables such as gender, age and marital status but also by hierarchical levels. They suggest that “higher level personnel in an organization might have greater understanding of why a specific technology is being implemented. Because of their closeness to the decision making process they might buy in to the innovation faster than end-users”. In their study it was found that different groups of organizational members have different perceptions of the benefits associated with an innovation.

Based on the literature review the aim of the S&OP activities, how APS can support each activity, and the potential benefits of using APS in the process, are proposed in Table 1. In the two first activities the demand planning module could supports the personnel developing a consensus forecast and a preliminary plan for future sales and delivery volume with help of statistical methods and demand planning tools. In the third activity the multi-site production planner supports the personnel creating a preliminary production plan by offering functionalities such as integration of certain entities and optimization models. APS modules can support step four and five, adjust and settle the plans by making information visible for everyone and offer scenario analysis. The benefits deriving from APS systems usage can be related to decision support, planning efficiency, or learning effects. Studies indicate that the use of APS systems results in improved Decision Support by allowing for integration and optimization of plans, visibility of information, scenario analysis, and resulting in more feasible plans and realistic delivery promises. Managers and planners can therefore make proactive improvements and better decisions. The literature also reveals that APS systems increase Planning Efficiency, for example, by reducing overall planning time and focusing on data quality. Further, APS systems generate Learning Effects such as better understanding and confidence in planning, and enthusiasm. All these benefits should have cost and delivery service implications. However, as the focus of this paper is on how APS systems support the S&OP process, the overall business performance related benefits (lower inventory levels, better service levels, shorter lead-times, cost savings etc.) are outside the present scope.

S&OP activity	Aim of the activity	Potential APS support	Potential benefits
1	Creating a consensus forecast	Statistical forecast methods, demand planning tools able to integrate different departments/companies	*Decision support:* feasible and optimal plans, integrated plans, realistic delivery promises, visibility of information, and proactive planning *Planning efficiency:* reducing the overall planning time, focus on data, and high quality of data *Learning effects:* confidence in planning, gained knowledge, and enthusiasm
2	Creating a preliminary delivery plan		
3	Creating a preliminary production plan	Possibility to integrate several entities, coordination of different functions, possibility to use optimization models to find the most feasible solution	
4	Adjusting delivery and production plan	Visibility of information, scenario analysis, for example what-if analyses of the impact in resource availability and customer demands	
5	Settle delivery and production plan		

Table 1: The aim of the S&OP activities, how APS systems can support each activity and potential benefits from using APS in the S&OP process.

4. The case company

In this section the case company is presented. In order to understand the context, a short background to the case company is given. Thereafter the use of APS in the S&OP process is described.

4.1 Background

The case firm is a company in the chemical industry that manufactures, markets, sells and distributes chemicals used at the surface of other chemicals. The case firm employs 1,100 people divided into three regional organizations: America, Asia, and Europe, the latter of which is studied here. The European division has three production sites, each year producing 110,000 tons, or approximately 1,000 products. Many of the products are manufactured in more than one process step, often involving more than one production site, which means that there is a large flow of intermediate products between the three sites. Every month, the European division purchases a certain amount of products manufactured by sites in America and Asia as they do not have the technology in-house. The European division also has contract manufacturing at fifteen production sites. In case of capacity shortages, it is possible to use idle capacity at other sites or to purchase capacity from contract manufacturers and/or regional organizations. The customer can be found all over the world, in different market segments and with different commercial and strategic values. The European division has about 70-80 suppliers located in different countries.

In order to coordinate the material flows between the production sites and keep away from sub optimizations, a centralized planning organization and an S&OP process was established in 2000. Shortly after the process was introduced it was recognised that the centralised planning organisation needed better control over the processes. Consequently, three APS modules were implemented in 2002 as the support tool for the planning process and has been used since then: 1) the sales module, which generates the statistical forecast using various forecast methods, 2) the demand planning module, where all forecast information, sales histories and outstanding orders are available and 3) the multi-site master planning module, which calculates an optimized production plan (how much and which volumes each of the three sites should produce so that every demand and target level is fulfilled at the highest contribution margin) in a linear programming (LP) model for the three production sites.

The users involved in the S&OP process is divided into four user groups: 1) the central planning organization, consisting of one supply chain manager and two supply planners, 2) the demand side actors, consisting of four business managers and forty sales managers, 3) the supply side actors consisting of three contract manufacturers, four production managers, and seven site schedulers[2], 4) and the managerial group, consisting of the CEO and the operations manager. The centralized planning organization is formally responsible for setting up and running the APS based planning. They also act as a centralized planning function. They work actively with the involved parts, they plan meetings and work with education and training. The sales managers work directly in the sales module whereas business managers use the demand planning module to view information. The supply side uses the multi-site master planning module to plan production and scheduling. The managerial group does not use the modules in their daily work but participate in various meetings supported by the demand planning module and the multi-site master planning module.

4.2 Use of APS in the S&OP process
S&OP consists of a demand planning sub-process and a supply planning sub-process. Figure 3 shows the use of the modules in the planning sub-processes and the actors involved. In the bottom of the figure the APS supported S&OP process is presented following the five steps identified in the literature.

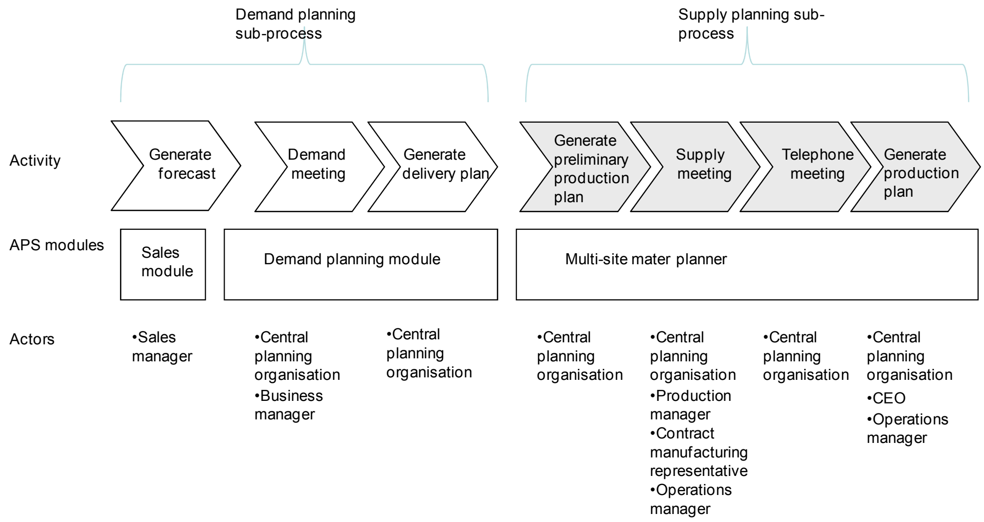

Figure 3: Planning process, APS support, and actors

[2] The site schedulers are not actually part of the S&OP process but as they use the input from the S&OP process to plan production their experiences are important

Activity 1*: Forecast future demand.* In the beginning of the month the sales managers put together a sales forecast. This is a combination of a statistical forecast produced by the sales module and the sales managers 'own forecast, based on experience for each stock keeping unit and customer for the coming 18 months.
Activity 2: *Prepare preliminary delivery plan.* In the monthly demand meeting the business managers and the central planning organization meet to prepare the demand plan. During this meeting issues such as forecast accuracy, possible sales-increases, and specific customer profitability, are discussed with the help of the information in the demand planning module, visualized on screen. The central planning organization draws up the final demand plan after the demand meeting.
Activity 3: *Prepare preliminary production plan.* The central planning organization is responsible for creating the preliminary production plan and this is done with the help of the multi-site production planner module. The delivery plan is automatically sent to the multi-site production planner module where it is converted into a preliminary production plan, taking the bill of materials, stocks, capacities, intermediates, production times, transportation times, and costs into account. Generally, the centralized planning organization runs several scenarios to analyze what happens if demand changes.
Activities 4 and 5: *Adjust and settle delivery plan and production plan*. The central planning organization, the operation manager, the production managers and the contract manufacturing representatives meet in the monthly supply meeting to discuss capacity, bottlenecks, inventories and whether it is possible to meet the demand. The preliminary supply plan is the basis for this meeting. The centralized planning organization also has a telephone meeting with the American and Asian divisions to discuss common material flows. After the supply meeting and the telephone meeting, the multi-site master planning module is updated with actual stock balances. A final production plan, made at stock keeping unit level and showing the volumes needed for the coming 18 months, is generated. Every second month an S&OP meeting is conducted where the CEO, the operation managers and the central planning organization meet to discuss remaining problems and to identify risks.

5. Results

In this chapter the experiences of using APS systems in the S&OP process at the case company is presented. First the results from the questionnaire are presented, followed by the results from the interviews.

5.1 The ranking of the benefits

The S&OP process consisted of two sub-processes involving many different actors. In the first sub-process APS were used to support the demand side actors and central planning organization in the daily work and the demand planning meeting. In the second sub-process APS supported the supply side actors, the central planning organization in the daily work and the supply meeting. Every second month an APS system was also used to support the S&OP meeting where the CEO, the operation managers and the central planning organization met. Separate analyses were therefore conducted for the user group's perceived benefits in their daily work and in meetings (demand planning meeting, supply planning meeting, S&OP meeting).

Figure 4 summarizes the answers of the user groups' perceived benefits in the daily work. It is not possible to compare the significant differences between the user groups' mean values as the number of actors, hence the number of answers, in each group are small and quite different. Still, some tendencies are found: two types of benefits are ranked highly by all user groups, namely that the APS system "allows visualization of information" and "makes the information easy to access". The graph representing the ranking of the central planning organization shows that most of the Decision Support benefits and Planning Efficiency benefits are ranked high. The demand side actors gave the highest ranking to the Learning Effect benefits whereas the Decision Support benefits and the Planning Efficiency Benefits were not ranked as high. Except from the commonly highly ranked benefits, two other benefits that were not connected to Learning Effects stand out as highly ranked; that the use of APS "results in a reliable demand plan" and that it "gives focus on data quality". The supply side actors ranked most benefits connected to Planning Efficiency the highest. Two benefits concerning Decision Support stand out as highly ranked except from the two Decisions support benefits that all actor groups had in common and that was that the use of APS "gives a common supply plan for the three sites" and "makes it possible to analyze unexpected events"

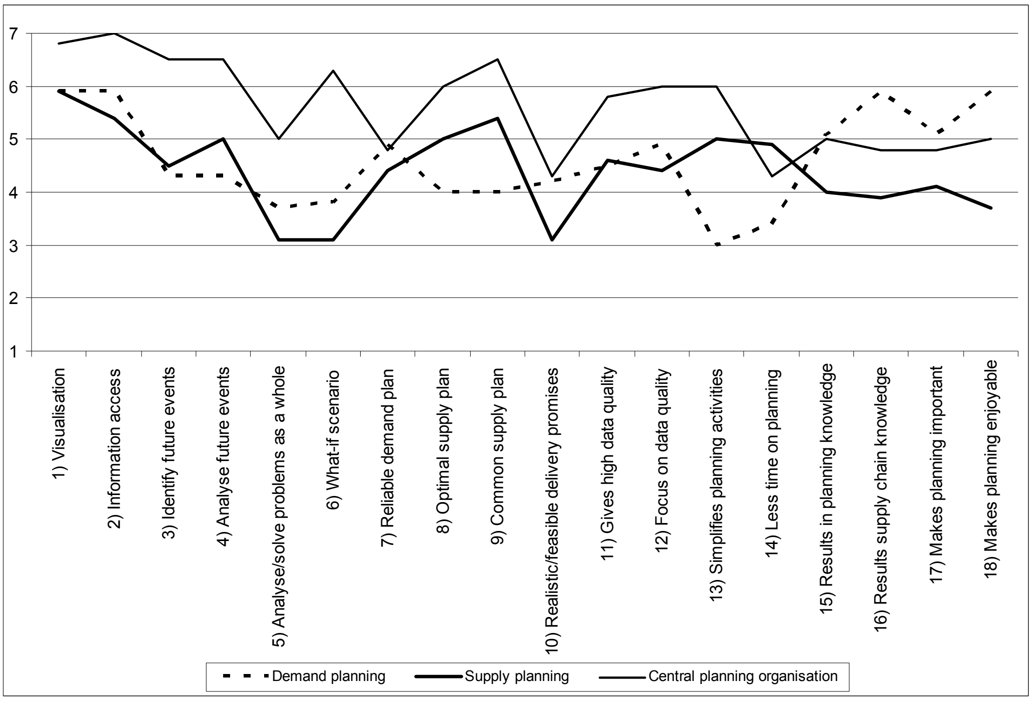

Figure 4: The users' perceived benefits in their daily work. The y-axes represent the level of agreement that the respective benefit is received, is graded on a seven point scale, where 1= strongly disagree, and 7= strongly agree. The twenty benefits are presented on the x-axes.

In figure 5 the benefits perceived in the three meetings are given by the meeting participants. As can be seen in the table the mean values are quite similar in the three meetings. In all meetings the Decision Support benefits "make information easy to access" and "identify and analyze unexpected events" are ranked high. At the demand planning meeting the Decision Support benefit that APS "results in a reliable demand plan" stands out as highly ranked. Also the participants at the demand meeting see many benefits connected to Learning Effects. The actors participating at the supply meeting rank the Decision Support benefit that "APS gives a common supply plan for the three sites" high. At the S&OP meeting the benefits that APS "makes it possible to analyze the problem picture and solve the problem as a whole" and that APS "gives a common plan for the three sites are ranked high".

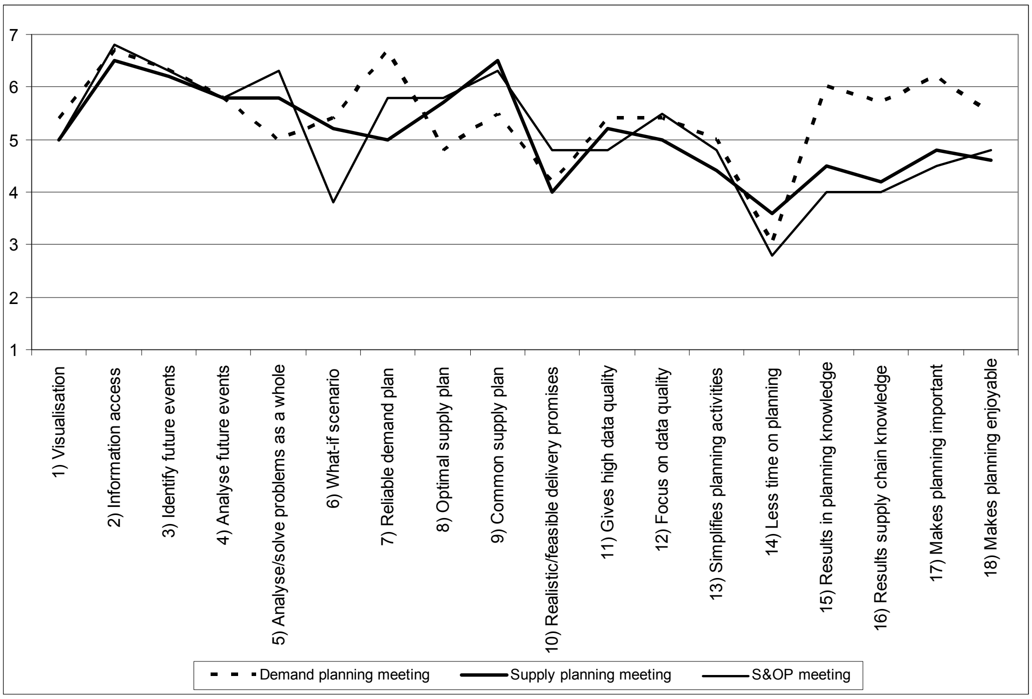

Figure 5: The meeting participantsperceived benefits ranked from a scale 1 to 7 where 1 = strongly disagree and 7 = strongly agree.

5.2 Experiences from the actors

In order to interpret the results from the questionnaire, interviews with the actors in the S&OP process have been conducted. The subjective experiences of the actors are presented by the user group below.

- The central planning organization perceives that the organization has obtained a comprehensive view that was not there before. The production sites have started to communicate and the majority of the employees have understood that it is important to cooperate to reach the common goals and that they belong to the same company. The supply planners and the supply chain manager stress that APS modules have provided them with more and better information when decisions need to be made, which has made it easier to plan in advance.. The actors in the central planning organization think that they could have used the functionalities in the APS modules to a larger extent and emphasize that the problem is not the system but the input to the system, i.e. the access and quality of the forecast, lead-time and capacity figures.
- The business and sales managers perceive that the APS system supported S&OP process has made the discussions at meetings and between

different functions more sound since there are real facts to rely on. Consequently, it has become easier to create a realistic demand plan and replace ad hoc decisions with better supported decisions. Still, the output does not get better than the input and reaching a 100% forecast accuracy is "to cry for the moon", according to one business manager. Several sales managers also think that they put too much time in creating an accurate forecast for no use; "customers are guided by circumstances that are impossible to have control over".

- The production manager, the contract manufacturing representative and the site schedulers pressure that they now have a tool that supports them to better understand what is happening in the future. This also helps them to stay one step ahead. The highest value with the APS modules is considered to be that all factories are in the same system and that it is possible to make centralized plans. The general view is improved. However, contract manufacturers are not included in the model which according to contract manufacturing representatives is a pity as it is not possible to let the model decide from where (which contract manufacturer) it is beneficial to buy capacity. The production sites are no longer as dependent on the local knowledge as before year 2002 and they have a tool that supports them with the demand forecast and long term planning. Because of this, the time to chase demand figures and to understand the situation has been reduced and more time can be put on problem solving at the sites. A problem noticed by many production managers is that they cannot always trust the plans.
- The managerial group stresses that it is important to have a decision support as a foundation for the meetings as the quality at the meetings gets much better when there are facts to rely on. The CEO means that APS is a support for the process to take place. It was a necessary condition for making the coordination and integration among the production site work. The operation manager thinks that it would be impossible to integrate all regional organizations in the same APS system as it would have torn the organization apart. There is more functionality in APS that Europe still has not utilized and the CEO and the operation manager see great potential of their APS investment. The CEO and the operation manager point out that one obstacle is to make the personnel understand the value of updating the data in the ERP system. It can easily become a vicious cycle if the system is not updated with the correct figures; the system gives odd figures which causes users to lose confidence in the system.

6. Discussion

The discussion is based on the literature review, the Delphi study and the case questionnaire and interviews. It consists of two parts: 1) Different types of APS benefits, 2) The use of APS and its perceived benefits.

6.1 Different types of APS benefits

The APS users in the case study perceived many benefits connected to decision support, planning efficiency and learning effects. This corresponds well with previous literature where improved decision support and better decision making (Brown et al, 2001; Gupta, 2002; Fleischmann et al, 2006), reduced planning effort and identification of necessary data (Fleischmann et al, 2006; Jonsson et al, 2007) and increased understanding and ability to act on supply chain issues (Gupta et al, 2002) were identified as benefits achieved by using APS in planning processes. The results from the case study also correspond with the results of the APS experts in the panel. Most of the perceived benefits were by APS users and APS experts lumped together at a medium place in the ranking and despite some small differences between each specific benefit it was benefits connected to decision support that stood out as the highest ranked. With respect to the similarities between the results of the APS users and APS experts and previous literature, it is reasonable to believe that the proposed list of the eighteen benefits (Appendix B) is relevant and should be possible to expect and to achieve when using APS in S&OP processes.

It was interesting to notice that the top one ranked benefit by the APS users was one of the lower ranked benefits by the APS experts. It was that APS "allows visualization of information". The reason that visualization was not ranked high by the experts was that they did not consider visualization a unique APS benefit but instead a general software benefit, also available in e.g. ERP systems. Nor was visualization as a benefit commonly mentioned in the literature when applying APS in the planning processes. This result may be unique to this case but it could also mean that visualization as an APS benefit has been underestimated by APS experts, and in previous literature. APS systems usually include user-friendly planning tools, such as interactive scorecards and drag-and-drop functionality (APICS, 2007). Indeed one of the benefits derived from this could be that it makes it easier to visualize information.

The case study confirms that the gross list of perceived benefits derived from the literature and APS experts is reasonable to accept. It is possible to achieve different types of benefits connected to decision support, planning efficiency and learning effects when using APS system in the S&OP process. Decision support benefits were, according to APS experts and APS users, the type of benefits most likely to be achieved.

6.2 The use of APS and its perceived benefits

Table 4 summarizes the aim of the S&OP activities, the use of APS, and the perceived benefits in each activity in the case company.

S&OP activity	**Aim of the activity**	**Potential APS system support**	**Potential benefits**
Activity 1	Creating the sales forecast	Statistical forecast methods, demand planning tools able to integrate different departments/companies	Results in a reliable demand plan, visualisation of information, makes information easy to access, resulting in good knowledge about the supply chain
Activity 2	Creating the delivery plan		
Activity 3	Creating a preliminary production plan	Calculating an optimized production plan in a LP model for the three production sites, what-if analysis if demand is changing	Results in an optimal production plan, makes it possible to identify/analyse future events, allow quantifiable what-if analyses, visualisation of information, makes information easy to access
Activity 4 and 5	Adjust and settle the production plan	Calculating an optimized production plan in a LP model for the three production sites	Gives a common an optimal production plan, visualisation of information, makes information easy to access, simplifies planning activities
S&OP meeting	Identify risks and discuss reaming and unsolved issues	Visibility of information	Makes it possible to analyse the problem picture as a whole, makes it possible to identify/analyse future events, visualisation of information, makes information easy to access

Table 4: the S&OP activity, its aim, the APS supported used and perceived benefits in the case company

It was presumed that since the aim of the S&OP activities is different, the usage of APS would differ, resulting in different benefits perceived in each activity. The case results showed that this was true to some extent. In the two first activities, with the aim of generating a delivery plan, one of the highest ranked benefits was that the use of APS resulted in a reliable demand plan. In steps three, four and five where the aim was to generate a production plan, one of the highest ranked benefits was that the use of APS resulted in a common and optimal supply plan. In the S&OP meeting, with the aim of identifying risk and solving problems, the benefits "make it possible to analyze the problem picture as a whole and identify future events" were ranked high. The result might seem obvious: if APS is used appropriately in the activities these are the benefits one would expect to perceive. Still there were other benefits perceived in the different activities that are not as obvious. Two benefits were ranked high in all

S&OP activities; the use of APS makes information easy to access and APS allows visualization of information. The reason for this can probably be explained by the history of the case company. Before APS was implemented the actors involved in the S&OP activities did not have any common tool where all information was collected and could be accessed. Therefore, the visibility at the company was consequently low.

The actors involved in the S&OP activities perceived different activities that were not connected to the aim of the activity. The benefits perceived in the two first activities foremost concerned learning effects. The benefits in step three concerned decision support. The benefits in step four and five concerned planning efficiency and the benefits in the S&OP meeting foremost concerned decision support. The reasons for this can be explained by how the APS system was used in the different activities and the user characteristics. In the two first activities the demand planning module was used which do not include so much decision support functionalities either than visibility and forecasting methods. This is why benefits derived from APS functionalities such as optimization and what-if scenario analysis is not found in the demand planning sub-process. One of the reasons why the planning efficiency benefits are not as highly ranked in these activities is that the sales managers and the business managers are responsible for creating the sales forecast . This was not the case before the APS supported S&OP process was implemented. The forty sales managers involved in the demand planning sub-process have worked isolated from each other, and located in different geographical places. Since the APS supported S&OP process was implemented they have been forced to work closer to each other and to the production sites. This may be the reason for why learning effects were ranked highly in the demand planning sub-process.

The multi-site production planner, including functionalities such as optimization, integral planning and what-if scenario analysis, was used in steps three, four and five. In these activities, more decision support benefits are apparent than in activities concerning the demand planning sub-process. Still, some functionality could have been used to a larger extent which probably would have influenced the perceived benefits. For example, the contract manufacturing representatives are disappointed that they are not included in the model and therefore are not able to support decisions in the model from where it is most optimal to buy capacity. The reason for not including contract manufacturers in the model is a lack of access to planning data. The findings from previous literature shows that the design of the system (Zoryk-Schalla, 2004) and access to planning data (Jonsson et al, 2007; APICS, 2007) influence the benefits one receives which is also evident in this study. The supply side actors have since APS was implemented reduced the amount of work as they do not have to chase sales figures, and the central planning organization now has a tool to support their planning. This, in turn, may explain why the actors involved in the supply planning sub-process see many benefits in the planning efficiency. The managerial group and the central planning organization, with a good knowledge and understanding of the S&OP process participate in the S&OP meeting. This may be the reason why learning effects were not as highly ranked here. Instead focus is on decision making and this is where the actors foremost see benefits.

The case study analysis shows that the benefits perceived in the S&OP activities are a bit different and that it depends on the aim of the activity, how the system is used, i.e. which functionality that is exploit and user characteristics. This corresponds well with the conclusions made by Amoako-Gyampah (2004) who found that different groups of organizational members have different perceptions of the benefits associated with an innovation. How the system is used is influenced by factors such as system design and access to planning data.

7. Conclusion and further research

The purpose of the article was to explore what potential benefits could be achieved by using APS systems in the S&OP process. A gross list, consisting of eighteen benefits divided into three types of benefits; decision support, planning efficiency and learning effects, was derived from a literature review and in a Delphi type of study with independent APS experts. In order to understand if benefits were different in the S&OP activities the list was tested in a case study. The most common type of benefits was decision support benefits, according to APS users and APS experts. The case study indicated that the decision support benefit "visualization of information" has been underestimated in previous studies and by APS experts. The case study analyses showed that the benefits perceived in the different S&OP activities differed. In the demand planning sub-process, actors perceived that the use of APS resulted in a reliable demand plan, good knowledge about the supply chain and made the planning activities more enjoyable. In the supply planning sub-process, the actors perceived that the use of APS resulted in a common and optimal supply plan and simplified planning activities. In the S&OP meeting, the use of APS made it possible to analyze the problem picture as a whole and to identify/analyze future events. The reason for the different results could be explained by the aim of the activity, how APS was used in the activity (which functionality that was exploited), the user characteristics (expectations, knowledge), the design of the model and access to-, and quality of planning data. The findings have several managerial implications. They could e.g. assist companies in understanding the potential benefits they can expect from its use in the S&OP process. The case study analysis gives further insight into how APS can be employed and which benefits different APS user categories can expect when they are used in an appropriate way.

It is always difficult to identify potential benefits by using an information system since benefits are different depending on whom one asks and what level of analyses one applies. Besides, it is difficult to isolate the contribution of the information system functions from other contributions to performance. Indeed, one could argue that some benefits in the proposed list derived in this paper should be excluded or that some benefits are missing. The material written on this topic is comparatively small, therefore, study is relatively exploratory and should be followed up in order to verify and generalize the findings about APS usage and its benefits. Benefits were examined by individual users' perceptions. However, a mix of surveys, interviews, and observations was used for the analysis. This should be sufficient in order to secure the reliability of the findings.

The study opens several opportunities for further research. Even though most of the perceived benefits and the lack of potential benefits could be explained by the case-unique usage, the cause and effect relationship between the potential benefits and its antecedents were not explored in detail. It would thus be valuable to further explore and explain how individual antecedents and different configurations of antecedents affect benefits. The focus here has been on benefits but there is also a cost side of APS which may constrain its usability. To understand the total APS performance, it is necessary to balance the costs and benefits of usage. These could be examined in further research. Finally, since the study only covers the sales and operations planning process, it may be interesting to study the potential benefits in other planning processes in which APS system is used.

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Appendix A – Expert panel ranking of benefits

Benefit type	**Specific benefit**	**Corresponding benefit in Appendix B**	**Grade***
Decision support	1. Allows information visualization and access	1,2	2
	2. Allows identification and analysis of unexpected events	3,4	3
	3. Makes it possible to analyze the problem picture and solve the problem as a whole	5	15
	4. Allows quantifiable what-if scenario analysis	6	7
	5. Gives reliable demand plan and delivery promises	7,10	13
	6. Gives a common supply plan	9	22
	7. Gives a feasible and an optimal supply plan	8	2
Planning efficiency	8. Gives focus on and results in high data quality	13,14	4
	9. Results in simplification and less time spent on planning activities	15,16	5
Learning effects	10. Gives learning effects about planning and supply chain	17,18	4
	11. Increases the focus on planning tasks and organization	19,20	4

*Each of the 15 experts was asked to mark the three specific benefits they considered that the use of APS first and foremost results in. The most important benefit was given 3 points, the second most important benefit was given 2 point, and the third most important benefit was given 1 point. The grades in the column represent the sum of points from all 15 experts.

Appendix B –The potential benefits derived from literature, a Delphi study and interviews at the case company

Benefit type	Specific benefit	Corresponding benefit in Appendix A
Decision support	1. Allows visualization of information	1
	2. Makes information (e.g. customer, markets, capacity) easy to access	1
	3. Makes it possible to identify unexpected future events	2
	4. Makes it possible to analyze unexpected future events	2
	5. Make it possible to analyze the problem picture and solve the problem as a whole	3
	6. Allows quantifiable what-if scenario analysis	4
	7. Results in reliable demand plan (low forecast error)	5
	8. Give an optimal (consider capacity, lead times etc.) supply plan	7
	9. Gives a common supply plan for the three sites	9
	10. Gives a demand plan that can be used without changes	5
Planning efficiency	11. Results in high data quality (e.g. capacity, lead times, safety stocks, customer data)	8
	12. Gives focus on data quality	8
	13. Simplifies planning activities	9
	14. Lead to less time spend on planning activities	9
Learning effects	15. Results in good knowledge about the planning processes	10
	16. Results in good knowledge about the supply chain	10
	17. Makes the planning activities important	11
	18. Makes the planning activities enjoyable	11

Paper III

How to utilize advanced planning and scheduling systems in sales and operations planning

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Abstract

Purpose: The purpose of this article is to increase the understanding of how to utilize APS functionalities in S&OP processes.
Design/methodology/approach: A theoretical framework is developed explaining which functionalities to use in different S&OP processes. The empirical analysis is based on a single case study at a company in the chemical industry that uses APS system support in the S&OP process.
Findings: Integral planning, optimization, concurrent priority and capacity planning and what-if simulations are APS functionalities identified as important support in S&OP processes. The functionality used is a matter of the complexity in planning tasks, the overall aim of the process, and obstacles in the form of managerial, technical and people problems. The S&OP process does not need to be very mature in order to benefit from APS. Still, as APS is an expensive investment it is important to weigh benefits against costs, in many situations it may be more appropriate to make use of more simple tools. To fully use the APS potential one needs to have high planning task complexity and aim for optimization. However, there seems to be a limit for how much complexity a company can handle as the obstacles are increasing with increased planning task complexity.
Research limitation/implication: The empirical analysis is based on a single case study. I.e. the findings are mainly valid for this case unique context.
Practical implication: The practical use of APS is in general low in most companies. The findings about how S&OP task complexity and S&OP aims to affect the need for using APS functionalities should be an important knowledge in guiding companies setting up S&OP processes. The frameworks developed in this article could be used for companies assessing the APS functionality need in S&OP processes.
Originality/value: The knowledge about how APS functionalities can be used in the S&OP process was previously unexplored. This paper fills some of these gaps. Our article generates theoretical frameworks and explores how APS can assist more advanced S&OP processes.
Keywords: Sales and Operation Planning (S&OP), Advanced Planning and Scheduling (APS) systems, planning task complexity, functionality, case study.
Paper type: Single case study

1. Introduction

Sales and operations planning (S&OP) is a business process that links the corporate strategic plan to daily operations plan and enables companies to balance demand and supply for their products (Proud, 1994; Grimson and Pyke, 2007). When managed in an appropriate way the S&OP process is supposed to generate many benefits to the company in the form of improved customer service, reduced inventory levels, shorted customer lead times as well as possibilities to react to new business opportunities (Wallace, 2004; Vollmann et al, 2005; Bower, 2006). Traditionally, S&OP has aimed at integrating intra-organizational functions and at creating consensus among one set of goals and plans (Feng et al, 2008). However, in line with the industry development, it will most likely become more important to take a supply chain perspective by aiming at developing optimal plans, while taking product dependencies and resource constraints into consideration (Affonso et al, 2008). An increased number of relationships, information flows and material flows within the organization and/or via the organization's downstream and upstream partners together with an aim to generate optimal sales and operations plans, means that the planning tasks in the S&OP process becomes more difficult to handle.

Many companies and researcher have placed a need of more advanced software supporting S&OP planning tasks. Functionalities such as optimization techniques (Vieria and Favetto, 2006), seamless integration between aggregated and detailed plans, S&OP workbench (Wallace, 2006), what-if analysis tools (Michael, 2007) have been suggested as appropriate for supporting S&OP planning tasks. Up to the present time research on S&OP has focused on its definition, processes, implementation procedure and benefits after implementation (Feng et al, 2008). Very few contributions have addressed how software systems can support the S&OP process. In this paper we argue that existing Advanced Planning and Scheduling (APS) systems include the functionalities needed for supporting S&OP processes. APS is defined as "*any computer program that uses advanced mathematical algorithms or logic to perform optimization or simulation on finite capacity scheduling, sourcing, capital planning, resource planning, forecasting, demand management, and others. These techniques simultaneously consider a range of constraints and business rules to provide real-time planning and scheduling, decision support, available-to-promise, and capable-to-promise capabilities. APS often generates and evaluates multiple scenarios*" (APICS, 2007).

In many situations, simple Excel spreadsheets may be sufficient while APS software modules are necessary S&OP support in other situations. The knowledge about when and how to use the more advanced functionalities is scarce. It is therefore interesting to find out in which situations it is appropriate to make use of the functionality in APS systems. This is especially true when considering the fact that APS systems is an expensive investment and many companies do not receive the benefits they expect (Stadtler and Kilger, 2005). In general APS systems are argued to support complex planning tasks (Setia et al, 2008), which are also supported by empirical studies of companies using APS systems (Brown et al., 2001; Gupta et al., 2002; Fleischmann et al., 2006; Jonsson et al., 2007). Firms with complex tasks characterized with a large number of product categories, frequent changing demand patterns and uncertain supply conditions can receive great benefits, while firms with less complex products or narrower product lines may find negative returns from APS systems due to the additional effort required to manage these tools (Setia et al, 2008). Thus the starting point of this paper is that APS systems are suitable in S&OP processes characterized by complex planning tasks. Still, it is not enough to have a good task-functionality fit (Guimaraes et al, 1992; Goodhue and Thomson, 1995) in order to generate value through APS systems. The APS functionality used also needs to match the business aims (Stadtler and Kilger, 2005; Setia et al, 2008). Except from the overall aim of the process, the S&OP process is made up of several activities, for example forecasting future demand and preparing preliminary production plans with different aims involving different actors and planning tasks (Jonsson and Mattsson, 2009). It is therefore reasonable to believe that different types of APS functionalities are needed in these activities. There are, however, several factors rendering or obstructing how the functionality can be used successfully. Cox and Clark (1984) identify three problems when implementing and using manufacturing planning and control systems; management problems e.g. lack of cooperation and procrastination, technical problems e.g. system design and rescheduling and people problems e.g. system education an system acceptance. We believe similar obstacles important to overcome also when using APS in the S&OP process.

The purpose of this study is to increase the understanding of how to utilize APS functionalities in S&OP processes. This is done through the development of a theoretical framework explaining when to use APS systems in different S&OP processes and the obstacles important to consider. A single case study research is conducted to further increase the understanding on how different APS functionalities support different S&OP activities. The outline of the paper is as follows: first the aim of the S&OP process and the S&OP activities are presented. The S&OP planning task complexity is also defined. Thereafter we propose for which S&OP aims and in which planning tasks it is appropriate to utilize APS functionalities .We also present which obstacles that might render the functionality-task-aim match. The methodology used in the study is described and a presentation of the case study is given. The case study analysis comprises the S&OP planning task complexity and the use of APS functionalities in the S&OP process and the users' experiences. The discussion explores the functionality needs in the S&OP process, the impact of the S&OP aim and the task complexity level on APS needs and the obstacles for using APS in S&OP. Figure 1 presents the design and structure of the analysis. The paper ends with a summary of the main conclusions, limitations and further research directions. The contribution of this paper is both managerial and theoretical as the paper provides an extensive framework for which APS functionality is needed in S&OP processes and which obstacles to consider when using APS in S&OP as well as explores how APS functionalities can support different S&OP activities.

2. Development of a theoretical framework

First the S&OP process is described, followed by an identification of the S&OP planning task complexity. The invention and definition of the planning tasks complexity is the first part of the theoretical framework. Thereafter the APS functionality appropriate to handle complex S&OP tasks and S&OP aims are proposed together with obstacles for making it work. The matrix developed for which functionalities to use in different S&OP processes, is the second part of the framework.

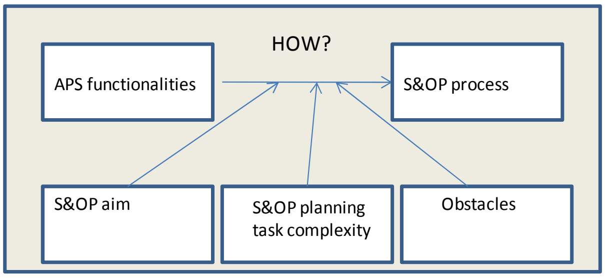


Figure 1: Design of the analysis

2.1 The S&OP process

Sales and operations planning (S&OP) is normally a monthly-based tactical planning process carried out in consecutive steps with a number of key persons from different departments involved (Dougherty and Gray, 2006; Feng et al, 2007; Jonsson and Mattsson, 2009). Traditionally, the most important overall aim of the S&OP process has been to create a platform for cooperation and coordination, and to create consensus among one set of goals and plans (Ling and Goddard, 1988; Proud, 1994; Feng et al, 2008). A second type of overall S&OP aims, which has not been very much in focus in the past but is expected to increase in focus in the future, is to generate optimum plans with optimal overall supply chain profit as the target function (Grimson and Pyke, 2007). According to Grimson and Pyke (2007), profit optimization cannot be reached unless the business processes and the information processes are mature. They use a one to five ranking scale across five dimensions (meetings and collaborations, organization, measurements, information technology and S&OP plan integration) to classify the maturity level of S&OP processes. A Stage 1 company does not have any S&OP process whereas Stage 5 relates to a company with a proactive S&OP process characterized by event driven meetings, real-time access to external data, seamless integration of plans, profit focused processes, integrated S&OP optimization software. A Stage 5 company is also a company where S&OP is understood as a tool for optimization. In general the following or related, consecutive steps are included in the S&OP process (e.g. Ling and Goddard, 1988; Wallace, 2004; Grimson and Pyke, 2007; Jonsson and Mattsson, 2009):

- Step 1: The marketing or other responsible department produces a forecast of the coming planning period's expected demand.
- Step 2: The marketing or other responsible department prepares a preliminary plan for future sales and delivery volumes. Previous sales and delivery plans should be compared with volumes actually delivered.
- Step 3: The production departments and those departments responsible for the procurement of start-up materials for manufacturing, will prepare preliminary production plans.
- Step 4: This step involves a reconciliation meeting between the managers of the company's marketing-, production-, financial-, procurement- and logistics departments. When consensus has been reached, a proposal is

established and a recommendation is made for a final delivery plan and production plan for the coming planning periods.

- Step 5: The proposals for a delivery plan and production plan, including any other preliminary decisions taken as a result of plans drawn up, are put forward to the company's top management group. When an agreement has been reached, the members of the management group meeting will settle the delivery plan and the production plan.

2.2 S&OP planning task complexity

Complexity has been discussed in many fields, and there is a broad range of definitions of what it means (Bozarth et al., 2008). In this article, planning task complexity arises if one or more of the following attributes exist:

- a high number of entities (Scuricini, 1998)
- a variety of entities (Scuricini, 1998),
- dependencies among the entities (Mason, 2007),
- uncertainty (Milgate, 2001),
- constraints (Yates, 1978).

The complexity of the planning task appearing in the S&OP process is the five mentioned complexity attributes exhibited by the material flows, relationships, and information flows that arise within any of the three complexity areas: the organization (internal complexity), or via the connections with the organization's downstream and upstream partners (downstream and upstream complexity). [1] (see Table 1)

Table 1: The S&OP planning task complexity

Complexity area	**S&OP task complexity attributes**				
	High number of entities	Varieties of entities	Dependencies among entities	Uncertainty	Constraints
Internal complexity					
Downstream complexity					
Upstream complexity					

Internal complexity: The material flow within the organization becomes more difficult to handle if the product variety is high or if the number of products increases (Milgate, 2001). If products need to be processed at different sites and share material and production facilities, there will probably be a need for coordination and integrating planning. A few examples of sources of uncertainty include machine breakdowns, rush orders and manufacturing yield. If people with different interests need to come to an agreement, the complexity increases. According to Buonanno et al. (2005), business units characterized by high interdependency show a critical need for coordination and control of business activities.

[1] Notice that the level of analysis in this paper is by organization as we will examine complexity empirically by organization. However, complexity could be examine at many levels e.g. by production site or supply chain.

Downstream complexity: As the number of customers increases, the magnitude of the tasks relating to customer relationships and demand management increases (Vollmann et al., 2005). Different types of customers are also more likely to vary depending on qualifiers and order winners, and by creating potential misalignments between manufacturing capabilities and customer needs (Bozarth et al., 2008). Customers' demands place constraints on the material flow. Downstream uncertainty implies a predictability of market demand (Milgate, 2001). A classical example is the bullwhip effect (Van Landeghem et al., 2002), which demonstrates how a lack of coordination in ordering policies, inadequate forecasting methods, and a high number of echelons in the supply chain can lead to wide fluctuations in upstream ordering patterns (Milgate, 2001;Van Landeghem and Vanmaele, 2002; Bozarth et al., 2008) .

Upstream complexity: Adding suppliers increases the number of information flows, material flows, and different kinds of relationships that must be handled. If a company uses several suppliers for one product, and those suppliers are not able to supply the whole volume, and the suppliers differ in quality of performance, then complexity will increase. If products are sourced globally, the number of complicating factors such as import/export legislation, cultural differences, and more uncertain lead times grows (Bozarth et al., 2008). Uncertainty refers to the difficulties for suppliers to keep promised lead times and the availability of resources. Long and unreliable supply lead times increase complexity and create problems in planning and control that may jeopardize delivery performance (Bozarth et al., 2008).

2.3 APS functionalities in the S&OP process

Provided that the APS system can be used effectively the following common APS functionalities should be of vital importance for S&OP;

- Integral planning: Means that it is possible to include more entities in the model than one. For example it is possible to create aggregated production/sales/distribution plans for several entities (Stadtler and Kilger, 2005).
- Optimization: Refers to the possibility to use optimization models to find the solution that is most feasible regarding some predefined criteria, such as minimizing costs or maximizing profit. The optimization models are either exact ones, such as Linear programming (LP) and Mixed Integer programming (MIP), or heuristics e.g. near optimal solutions (Stadtler and Kilger, 2005).
- Concurrent priority and capacity planning: Means that it is possible to use finite capacity and material constrains to synchronize planning of available resources and material flows (Hamilton, 2002).
- Simulation: Refers to the possibility to make use of different scenarios. For example, descriptions of likely future events (Setia et al, 2008).

The need for APS functionalities in the S&OP process depends on the overall aim of the S&OP process and the S&OP planning task complexity. The APS need should be lower when a clear optimization aim is abscent and when the planning task complexity is lower (See Figure 1). Optimization is a necessary functionality when aiming at optimum plans. Integral planning, concurrent planning and simulation are important functionalities in complex task environments when several dependent entities are coordinated in an uncertain environment taking constraints into consideration. All four APS functionalities should be needed when both aiming at optimization and dealing with high complexity. However, all four functionalities may be relevant in all three APS need situations in Figure 2. Optimization normally also means concurrent priority and capacity planning, as well as simulation to test different scenarios. Dealing with complexity may also require scenario analysis and simulation which may require setting up optimization models. Often all four APS functionalities should, consequently, be S&OP enablers when either aiming at optimization, or when having a complex supply chain environment, or when both aiming at optimization and having a complex environment.

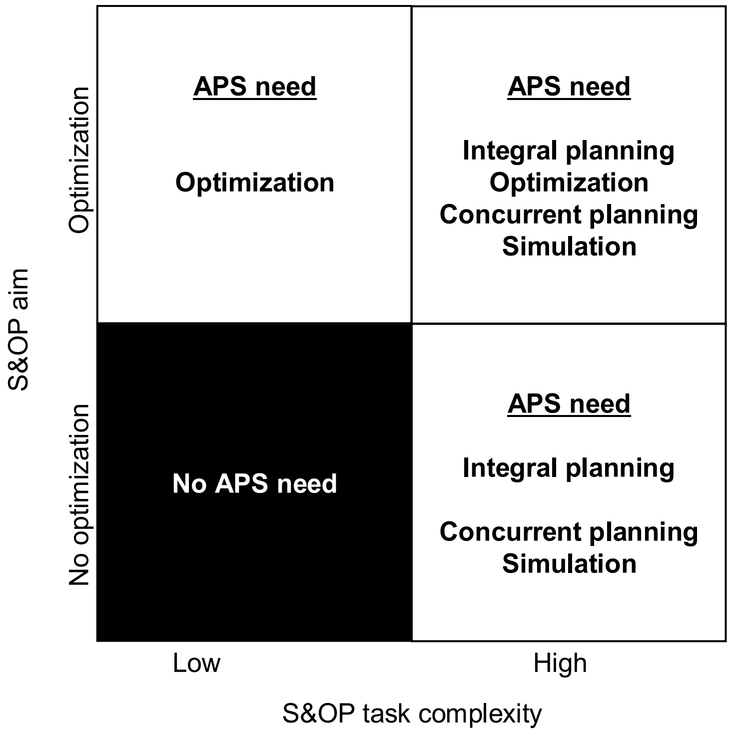


Figure 2: S&OP task complexity, S&OP aim and APS need. Quadrant I represents a situation with low S&OP task complexity and no optimization aim. Quadrant II represents a low S&OP task complexity and optimization aim. Quadrant III represents a high task complexity and no optimization aim, and quadrant IV represents a high task complexity and optimization aim.

2.4 Obstacles

There are many factors that render or obstruct how successfully the APS functionalities needed may be used in practice. Based on the work by Cox and Clark (1984) we propose three types of problems that are important to consider when implementing and using APS systems: management problems, technical problems and people problems. The management problem consisted of poor prior planning, lack of co-operations, and procrastination. Technical problems were classified into system design, data structure and file integrity. Other technical problems were management of inventory levels and rescheduling. People problems included communication, system education, user participation, and system acceptance. More recent studies of APS system support these conclusions; Pibernik and Sucky (2007) identify that incongruence between the incentives of the organizations involved and lack of overall supply chain objectives may be some significant planning obstacles. Wiers (2002) emphasizes the importance of system integration and Statler and Kilger (2005) point out a strong coordination of planning tasks modules if APS functionality should be used successfully. Zoryk-Schalla et al (2004) stress that one of the most important factors in order to implement an APS system is consistent modeling. The importance of high data quality and access to the right data has also been put forward by many researchers (Zhao and Lee, 1993: APICS, 2007; Jonsson and Mattsson, 2009). If the planning process is subjected to data inaccuracies, poor recommendations may be made and cause users to lose confidence in the system. A system plagued with data errors and support problems would lead users to rely on manual and back-up systems as the only means to perform their jobs (Petroni et al, 2002). Acceptance and voluntary use of the information system is deemed a necessary condition for successful use and, according to Torkzadeh and Dwyer (1994), most information system failures result from a lack of user acceptance rather than poor quality of the system.

3. Methodology

Case study research is usually said to be preferable when the experience is rare and the contextual conditions unknown (Voss et al, 2002), where “how” and “why” questions are addressed concerning contemporary sets of events over which the researcher has little control (Yin, 1991). The purpose of this paper is of an exploring character which requires detailed investigation and a clear understanding of the entire planning process. This is why the case study is considered an appropriate research methodology here.

The case firm, a company in the chemical industry, was selected as it had a long and wide experience of using APS system to support all five steps of its S&OP process. The environment consisted of S&OP planning task complexity in terms of a high number and variety of products, production sites, suppliers and customers. Besides, there were dependencies among the production sites and some capacity constraints. The overall S&OP aim was to create a global delivery plan, coordinate the material flows among the many production sites and reach consensus among one common production plan. The case firm belongs to quadrant III in Figure 1: high S&OP task complexity and no S&OP optimization aim, meaning that there should be a need for APS support which qualifies the case as relevant. There are still quite few companies using APS applications in all S&OP steps. The case could, thus, be considered both a unique single case for studying APS usage in S&OP and also a revelatory single case, because of the limited existence of such cases few have earlier had the opportunity to study this (Yin, 1991).

Different methods were used to collect data from the case study; in-depth interviews, observations, and company documents; web pages, annual reports, brochures, manuals etc. In-depth interviews with over twenty persons at the case company were carried out. In general, multiple investigators were conducting the interviews as it increases the confidence of the findings (Eisenhardt, 1989). Interviews were carried out during 2007 and 2008, with people involved in the S&OP planning process and lasted about one and a half hours each. The personnel interviewed were either direct users (working with the APS modules) or indirect users (using the output from the APS modules) and they were asked about the S&OP planning tasks, S&OP planning activities, use of APS system in the S&OP process and their experiences of using APS in the process.

In order to enhance reliability and validity, a research protocol was designed. The protocol served as a prompt for the interviews as well as a checklist. It also contained the subjects to be covered, the questions to be asked and it indicated the specific data required. The protocol was tested in initial interviews with the organisation. The notes from the interviews were sent to the interviewees for feedback and checking of the data. If needed, interviews were also followed up by telephone or revisits were made to verify and clarify data. In addition, study visits were made at two of the three production sites and the authors took part in the daily work of the participants involved in the S&OP process and in the monthly planning meetings. Field notes were used for writing down impressions as they arose.

4. Case study

This section describes the use of APS in an S&OP process at the case company. First the S&OP planning task complexity is described. Thereafter the use of APS in the S&OP activities and the users' experiences of the APS supported process are presented to illustrate how APS functionalities support different planning tasks. The section ends by analyzing the functionality used to support the S&OP process.

4.1 S&OP planning task complexity

The case firm is a company in the chemical industry that manufactures, markets, sells, and distributes surfactants. The case firm employs 1,100 people divided into three regional organizations: America, Asia and Europe, the latter which is studied here. The internal complexity is made up of the large number of products and product varieties; the European division produces 110,000 tons yearly or approximately 1,050 products. There are three production sites in Europe with certain dependencies as most products are manufactured in more than one process step, often involving more than one production site. The European division purchases products from the Americas and Asia every month. Constraints remain in terms of storage, packaging, and capacity. In case of capacity shortage, it is to some extent possible to use free capacity at other sites.

The downstream complexity composes 1,400 customers in different market segments spread all around the world with different commercial and strategic values as well as growth potentials. The monthly forecast accuracy is higher than 90% on total aggregated level but on average 42% on the stock keeping unit level which is requested by the customer. This implies a high and critical demand uncertainty as the item value of stocked items is quite high and safety stocks therefore must be kept to a minimum. The customer expects delivery times of a couple of days but the lead time is much longer, which means that most products are made to stock. The upstream complexity constitutes 70-80 suppliers located in different countries and fifteen contract manufacturers. The case firm has many suppliers for each raw material, but it is difficult to deliberate on price as it is market based and the purchasing strategy is mainly used to secure against risks. Products are bought from contract manufacturers every month as the European division does not have the technology needed for producing all products and therefore suffers from capacity shortage. In general, the company receives materials from suppliers in time; however, there are some uncertain factors with raw materials.

4.2 Usage of APS in the S&OP process

Three APS modules were implemented in 2002 to support the S&OP activities: 1) the sales module, which generates the statistical forecast using various forecast methods, 2) the demand planning module, which is where all forecast information, sales histories and outstanding orders are available and analyzed 3) the multi-site master planning module, which calculates an optimized production plan. The APS supported S&OP process is presented below.

- Step 1: *Forecast future demand*. In the first step of the S&OP process the sales managers put together a sales forecast for each stock keeping unit level and customer for the coming 18 months. To the sales managers' support, the sales module is used which creates a statistical forecast based on the past three years sales- history. The sales managers complement the statistical forecast with their own experiences and the sales forecast is then automatically sent to the demand planner module.
- Step 2: *Prepare preliminary delivery plan*. The delivery plan at the case firm is created at a planning meeting where the central supply chain planning organization meets the business managers. During the meeting, issues such as forecast accuracy, possibility of increased sales and the potential of specific are discussed. To support this meeting the information from the demand planning module is visualized on a screen.
- Step 3: *Prepare preliminary production plan.* The central supply chain planning organization is responsible for creating the preliminary production plan. This is done with the help of the multi-site production planner module. The delivery plan is automatically sent to the multi-site production planner module where it is converted into a preliminary production plan. The bill of materials, stock, capacities, intermediates, production times, transportation times and costs are all taken into account. The APS multi-site production planner module then calculates an optimized production plan in a linear programming model for the three sites in Europe. The target is to fulfill every demand and to target inventory at the highest possible contribution margin. Generally, the central supply chain planning organization runs several scenarios to analyze what happens if the demand changes.
- Steps 4 and 5: *Adjust delivery plan and production plan and settle delivery plan and production plan*. The production managers, the personnel responsible for the contract manufacturers and the centralized supply chain planning organization discuss whether it is possible to meet the demand, capacity and bottlenecks at a second planning meeting. The preliminary production plan and the delivery plan are basis for these discussions. The centralized supply chain planning organization also has a telephone meeting with Asia and America to discuss common material flows. The reason for not including Asia and America in the linear programming model is that the number of products is considered too

low, compared to the work it would actually take to include them. After the supply meeting and the telephone meeting the APS multi-site production planner module is updated with actual stock balances and a final production plan is generated.

4.3 Experiences from the actors

In this section the subjective experiences from the actors working in the S&OP process is presented. The description is based on interview data.

The central planning organization stresses that the APS supported S&OP process has resulted in a comprehensive view that was not there before. Thoughts and beliefs have been replaced by facts and data. They consider it now easier to plan in advance, which has made it possible to reduce the staffing, hence the decrease in costs. According to the supply chain manager the APS modules have provided the central planning organization with more information when the decisions need to be made. The central planning organization considers that the greatest value of the APS modules are the simulation capabilities and the possibility of integrating many entities. They think that it now will be possible to make use of all functionalities to a larger extent and emphasize that the "problem is not the model but the input to the model".

The business and sales managers point out the dilemma with an accurate forecast. "One must understand that we never will reach 100% forecast accuracy". With the support of APS modules, the sales and business managers feel that they can handle more and it is not as much discussions. Some sales managers believe that they put too much emphasis into creating an accurate forecast seeing that they do not get as much back. It is interesting to notice that how satisfied or dissatisfied the sales managers are, to a large extent, has to do with the beliefs of their business managers.

The production manager and contract manufacturing representative stress that they now have a tool that supports them to better understand what is happening in the future, which helps them be one step ahead. One problem is that the consultants quit and it takes time for new consultants to learn the business. The highest value with the APS modules is considered to be that all factories are in the same system and that it is possible to make centralized plans. However, contract manufacturers are not included in the model which. according to contract manufacturing representatives, is a pity since it is not possible to let the model decide from where it is beneficial to buy capacity. The reason is that it is difficult to obtain the planning data needed form the contract manufacturers.

4.4 Matching S&OP planning task complexity, APS functionality used and experiences gained

Table 2 summarizes the S&OP planning task complexity and the APS functionality used in each S&OP activity as well as the experience gained in the case study. It is followed by an analysis of the functionalities used in the S&OP activities.

Table 2: The S&OP planning task complexity, the APS functionality used and the experiences gained in each S&OP activity.

S&OP process	**S&OP task complexity**	**APS functionality used**	**Experiences**
Forecast future demand	Downstream complexity: Number of entities:1400 customers Varieties: different market segment, grow potential etc Dependencies: No Uncertainties: 42% forecast accuracy Constraints: No	Integral planning (integrate different business units into the forecast process)	Less ad hoc, better discussion Dilemma of creating an accurate forecast
Prepare preliminary delivery plan			
Prepare preliminary production plan	Internal complexity: Number of entities: 101,0 00 tons/yearly Varieties: 1050 product variants Dependencies: regional organizations buy products from each other, products processed at several production sites Uncertainties: No Constraints: storage, packaging Upstream complexity Number of entities: 70-80 suppliers, 15 contract manufacturers Varieties: different technology Dependencies: many suppliers for the same raw material, some products need to be processed at several contract manufacturers Constraints: capacity, storage Uncertainties: some raw material	Integral planning (include all production sites) Optimization (which and how large volumes should be produced at each site where target level is fulfilled at the highest contribution margin) Concurrent priority and capacity planning Simulation (looking at what happens if demand is changing)	High value that one can make use of what-if simulations Better prepared for the future
Adjust and settle delivery and production plan	Downstream complexity Internal complexity Upstream complexity	Integral planning Optimization Concurrent priority and capacity planning	APS functionalities could have been used to a larger extent The problem is not the model but the quality of data High value that one can integrate production sites and create centralized plans

In the first two steps of the S&OP process at the case company, integral planning is used to handle the downstream complexity. It seems as the actors involved in these steps in general are happy with how the APS modules support the process. They perceive that the quality at the meetings has increased and that it is easier to plan in advance. However, the sales and business managers point out the dilemma of generating an accurate forecast as forecast data cannot exactly correspond with the reality, no matter the time or the tools used.

Step three in the S&OP process is affected by internal and upstream complexity and all four APS functionalities are used to handle this complexity (Table 2). In this step the preliminary production plan is generated with the help of finite planning, integral planning and optimization. What-if simulations are carried out to test the effects of changing demand. Some problems are pointed out from the actors involved in this step that could be connected to how APS functionalities are used to handle the S&OP planning task complexity. The three regional warehouses would have been, but are not, included in the model when creating the integrated production plan as the European organization buys products from Asia and the Americas every month and also in some cases when there is capacity shortage. Still, according to the actors, the pros/cons of doing so will not exceed the cost as the products transferred between the production sites are considered too few making it more appropriate to handle these material flows via telephone and email.

In steps four and five the final production plan is generated as an output from the supply planning meeting and the telephone meeting with the other regional organisations. Optimization, integral planning and finite capacity planning are used to support this step (Table 2). The experiences from using APS in steps four and five are that one is better prepared in the future and that one now spends more time on problem solving. The contract manufacturing representatives are disappointed that the contract manufacturers are not included in the model since this means that it is not possible to let the system decide which products should be produced by contract manufacturers based on predefined criteria. Nor is it possible to analyse from where it is most optimal to buy capacity. The reason for not including contract manufacturers in the model is the lack of access to planning data.

5. Discussion

The discussion consists of four parts: 1) The APS functionality needs in the S&OP process, 2) The impact of S&OP task complexity and S&OP aim on APS needs, 3) Obstacles for using APS in S&OP, 4) Managerial implications

5.1 APS functionality needs in the S&OP process

The planning tasks in the first two steps of the S&OP process in the case study were characterized by downstream complexity. The APS functionality used to cope with the S&OP task complexity was integral to the planning. In step three, there was more complexity than in step one and two as the planning task focusing on preparing preliminary production plans concerned both internal and upstream complexity. Here all functionalities were used to handle the situation; integral planning, optimization, concurrent priority and capacity planning and simulation. The APS functionality was expected to be used to its greatest extent in steps four and five as the planning tasks here concerned internal, upstream as well as downstream complexity. But this was not the case. In steps four and five only integral planning, optimization and concurrent priority and capacity planning were used. No what-if simulation was used. So does this imply a mismatch between the APS functionality needed and the APS functionality used? One could suggest that simulations with advantages could be used in steps four and five to prepare discussions and support decisions in the supply planning meeting. Instead, what-if simulations are now only conducted in step three by the centralized planning organization to test what happens if demand is changing.

Grimson and Pyke (2007) relate S&OP usage to different majority stages. The level of S&OP majority may explain the APS usage in the case company. We concluded that the company has enough complexity to utilize all four APS functionalities but it has not yet reached the majority stage to aim at profit optimization and fully utilize all APS functionalities, especially not in steps four and five of the S&OP process, where the functionalities were expected to have especially high potential. Its aim has been on integrating the organization and information system and settling a process for developing and reaching consensus among one common set of demand and supply plans among all business units. This could also be the explanation for why integral planning was considered the most important functionality by the actors in the case company. The company would most likely have benefited from more rigorous use of APS functionalities if aiming at preparing optimum and feasible plans in steps four and five, to support the planning meeting and concurrently generating optimal and feasible demand and supply plans.

The case study shows how several positive effects are reached from using APS functionalities for coordinating the organization and settling the S&OP process in a situation characterized of complex S&OP planning tasks. The users in the case study e.g. consider that it is easier to plan in advance and that APS provides them with more information when decisions are to be made. Integral planning was a highly demanded and valued functionality at the case company. As the most important aim of the S&OP process is to create cooperation, coordination and create consensus among goals and plans (Ling and Goddard, 1988; Bower, 2006) the results are not very surprising. Still, optimization, concurrent priority and capacity planning and more extensive what-if simulations should be some important enabler for more mature S&OP processes.

5.2 Planning task complexity and APS needs

In the case company it was found that a given degree of complexity was needed for the actors to think that it was worth using APS modules: the material flow between the regional organizations were not considered complex enough to be handled by the system and was instead taken care of by other means. This observation corresponds well with our logic that no optimization aim and low S&OP task complexity means no APS needs. It also corresponds with previous studies. Setia et al (2008) e.g. stress that companies with less complex products or narrower product lines may find negative returns from APS systems due to the additional effort required to manage these tools. The question one could ask is how much complexity that is needed in order to make the APS investment worth paying for? How many complexity attributes should exist and how high does each entity need to be in order to make the situation complex enough? Is it more appropriate to use APS if one has 100 entities and varieties but no dependencies, uncertainties and constraints compared to if one had a fewer number of entities and varieties plus dependencies, uncertainties and constraints? When trying to understand what “complex enough” means we need to look in detail into the internal complexity of the case company. The internal complexity consisted of a large number of products and product variants (1050 different end products). There were dependencies and constraints since many products needed to be processed at several sites and some products needed to be bought from Asia and the Americas. The company also suffered from capacity problems. In other words four of the five complexity attributes were represented. Still, the material flow, the information flow and the relationships between the European division and Asia and the Americas were not considered complex enough as there were not enough products transferred between the sites between the regional organizations. It therefore seems that what is considered complex "enough" is dependent on both the level of complexity of each individual attribute as well as the number of attributes.

We suggested that APS is especially beneficial when the S&OP process is characterized by complex planning tasks and the aim is to optimize the profit. Consequently, companies in Quadrant IV are the ones that have best potential to receive benefits from the APS investments. The case company in this study belongs to Quadrant III, where the aim is to create a platform for cooperation and coordination rather than to generate optimal plans (even though they use optimization to reach their S&OP aim). Several of the actors in the S&OP process also stress that the full APS potential is not used. It consequently seems as if a high S&OP task complexity is not enough for utilizing the full APS potential, but instead it is dependent on the S&OP aim.

The case study indicated that a given degree of complexity is needed in order to make the APS investment something for which it is worth paying. .It indicates that the complexity depends on the tradeoff between the effort of making it work and the potential benefits to gain from the investment. The case study also indicates that "high complexity" is a matter of the level of complexity of each individual attribute as well as the number of attributes. However, to fully utilize the APS potential one should have a mature S&OP process and aim for profit optimization.

5.3 Obstacles for using APS

The APS supported S&OP process in the case company has been active for six years; still the case company has not yet reached the highest maturity level of the S&OP process. One reason for this could be that the central planning organization has been responsible for the whole process development and for the APS implementation. The central planning organization has focused on coordinating material flows between the many sites and to reach consensus but has not aimed for optimization. This may instead have been the case if the S&OP project had been driven by the corporate management.

When it comes to technical problems, access to and quality of planning data have been put forward as obstacles for how the functionality in the APS application should be used. The central planning organization stresses that the problem is not the model but the input to the model, i.e. forecast and capacity figures etc. This is supported by previous literature where data quality and access to right data is identified as one important factor to consider for successful usage of information systems (Zhau and Lee, 1993; Petroni et al, 2002; APICS, 2007; Jonsson and Mattsson, 2008). Setia et al (2008) suggest that APS systems optimize operations more effectively if the constraints for factors of production include not only the factors within the firm but also these of the partner organizations. Indeed the linear programming model would have been more consistent with reality if contract manufactures were included and decisions could be made on where to buy capacity, based on predefined criteria. Still this was not possible as contract manufactures did not share planning data with the case company. An interesting question is if the obstacles increase with increased complexity?

Finally, the people problems are identified. For example, the production managers put forward the problem of new consultants that are not familiar with the situation of the company. Another problem is system acceptance, meaning that many sales managers under skeptical business managers also are skeptical. Acceptance of a system is a necessary condition for its use and, in fact, it is a main reason to why many information system investments fail (Torkzadah and Dwyer, 1993).

The case study shows that management problems, technical problems and people problems present obstacles for how successfully the APS functionality can be used. It shows that there are many more factors to consider and that the planning task complexity and the S&OP aim fit the APS functionality used.

5.4 Managerial implications

The study and its findings about how S&OP task complexity and S&OP aim affect the need for using APS functionalities should be an important knowledge for guiding companies in how to utilize APS in S&OP processes. Figure 3 presents a procedure for how the need for APS functionalities can be assessed:

1. Mapping S&OP task complexity: Complexity was defined as consisting of five complexity attributes and arising within the organization or in the downstream or upstream supply chain. The existing complexity can be mapped by estimating the existence of the five attributes internally, downstream and upstream, respectively. If several attributes exist or if some of the attributes are very high, then the complexity is considered high. The table in Step 1 in Figure 3 could support this mapping.

2. Identifying APS needs: The need for APS system support depends on the S&OP task complexity mapped in Step 1 and the aim of the S&OP process. There are two fundamental types of aims; 1) to create a platform for cooperation and coordination, and create consensus among one set of goals and plans, and 2) to generate optimum plans, for example, with optimal overall supply chain profit as the target function. All S&OP processes should have the cooperation and coordination aim but not all need to have the optimization aim. If positioned in quadrant I, then APS is not necessarily beneficial, but APS functionality should be an important support in quadrants II-IV, especially in Quadrant IV.

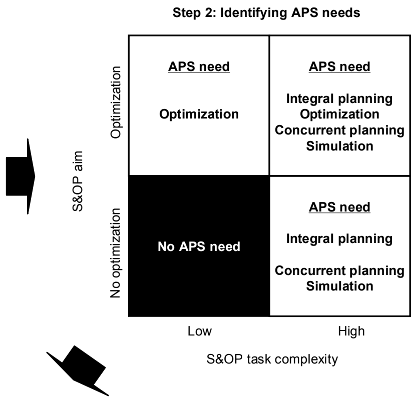
3. Identifying APS functionality needs: More detailed assessment is needed in order to identify which APS functionalities should be used in the different S&OP process steps. The table in Step 3 in Figure 3 is a rough guideline of what functionalities could be beneficial to use in the different S&OP process steps. The functionality needs will differ for companies positioned in different quadrants in the Step 2 matrix. If there are no S&OP task complexities, then there will be very small APS functionality needs in Steps 1 and 2 of the process.

If there is no optimization aim, then the optimization functionality need will be lower. However, the general APS needs (including optimization) are higher when a process involving frequent and thorough scenario analysis and what-if simulations is set up.

4. Identifying and minimizing APS obstacles: It is not enough to only conduct steps 1-3 in the suggested APS need assessment procedure. These steps help a company to understand if and which APS functionality to use as S&OP support. In order to benefit from APS usage, it is also important to understand and to reduce some APS obstacles. These can be related to management, technical and people obstacles. This study especially emphasized the importance of corporate management commitment in order to develop a fully proactive and mature process; information system integration and data quality in order to make the APS functionality work; and people education and knowledge to utilize the full potential of the APS support in the various steps of the S&OP process.

Step 1: Mapping S&OP planning task complexity

Complexity area	S&OP task complexity attributes					Estimated resulting complexity
	High number of entities	High variety of entities	Dependencies among the entities	Uncer-tainty	Const-raints	
Internal complexity						
Downstream complexity						
Upstream complexity						



Step 3: Identifying APS functionality needs

S&OP Step	S&OP planning task complexity	APS functionality needs
1. Forecast future demand 2. Prepare preliminary delivery plan	Downstream complexity	Integral planning
3. Prepare preliminary production plan 4. Adjust delivery and porduction plans 5. Settle delivery and production plans	Internal complexity Downstream complexity Upstream complexity	Integral planning Optimization Concurrent planning Simulation

Figure 3: How to utilize APS in the S&OP process

6. Conclusions and future research

The purpose of this study was to increase the understanding of how to utilize APS functionalities in S&OP processes. This was done with help of literature and a single case study where the APS functionalities used in different S&OP activities were analyzed and understood. The study contributed to theory by developing a structured framework and improving the understanding of the relationships between the APS needs and the APS usage in S&OP processes. Several issues for future research were generated, which was an important output of this study, since the study area is quite unexplored. The study also has important managerial implications, as the framework developed and presented in this article could be used for companies assessing the APS functionalities needed in the S&OP process. The case study analysis gave further insight into how APS functionalities can be used to support the different S&OP activities and which problems and benefits APS usage can result in.

Four APS functionalities were suggested to support S&OP processes; integral planning, optimization, concurrent priority and capacity planning, and what-if simulations. Two dimensions were argued to explain the APS needs for different types of S&OP processes. The need of APS functionalities were expected to increase with increased complexity in planning tasks and in processes with clear optimization aims. The case analyses showed that the functionalities needed were different in the five S&OP activities and that the functionality actually used was not only a matter of the task complexity and the overall aim of the S&OP process but also the obstacles in form of managerial problems, technical problems and people problems. The actors in the S&OP process received many benefits e.g. APS helped them staying one step ahead and they were provided with better information when decisions were to be made. This indicates that APS should be a suitable support when striving for consensus and coordination. However, what one must keep in mind is that APS is an expensive investment tool both in terms of money and time. Therefore, in some situations, other support tools are both easier and less expensive to use. Indeed, all S&OP processes should have the corporation and coordination aims which APS could fulfil with help of integral planning. However, if it is the only aim, and the task complexity is low, it is probably better to support the process with a simpler tool such as Excel. The case analysis supports this statement as it was shown that a given degree of complexity is needed in order to make it worth paying for the APS investment. There is certainty a trade-off between costs and benefits. This should not come as a complete surprise since it has been reported in previous literature. More surprising may be that there also seem to be a trade-off at the other extreme, i.e. a limit for how much complexity an organisation can handle. Even though the case company did not have high complexity or any optimization aim, many obstacles were identified as for example lack of corporate management commitment, lack of access and quality of planning data and education problems

We have identified three areas to follow up and further investigate in future research.

- The need of APS functionalities: This study shows that to fully use the APS functionalities one needs to have a high task complexity and to aim for optimization. It is most appropriate to use APS systems in mature S&OP processes characterized by high task complexity. This proposition can be tested and verified in future studies in order to generalise when to use APS systems in S&OP processes. It would be interesting to research which general conclusions can be drawn for when certain functionalities should be used in each S&OP step?
- S&OP planning task complexity: In future research it is interesting to investigate the meaning of “high enough”. I.e. how much complexity is needed in order to benefit from the APS investment? It is also interesting to define the type of complexity needed. For example, is it more appropriate to have many complexity attributes or perhaps a few complexity attributes where each attribute is high?

- Obstacles: Interesting future research should investigate if there is a limit for how much complexity an organisation can handle with APS. It is also interesting to investigate if there are other factors that are important to consider in order to successfully using APS in the S&OP process.

This study has some limitations. The framework developed has two dimensions, aim and planning tasks, hence it is suggested that when deciding if there is a need of APS functionalities there are only two dimensions to consider. One can, however, also argue for a third dimension. Many times planning processes have a great need of rescheduling and this would also place a need of APS functionalities. However, as we are focusing on the S&OP process where the need of rescheduling is not as dire, the S&OP need dimension is left outside the scope. In this study we only concentrate on three types of obstacles important to consider for making the use of APS successful. Indeed there are more factors that render or obstruct a successful APS usage, however, those covered here are generated from literature and should be important. Finally, the empirical analysis is based on a single case study, meaning that these findings are valid for the unique case context, such as the APS functionalities used to support medium complex planning tasks and coordination and integration aims.

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Paper IV

Shop floor characteristics influencing the use of Advanced Planning and Scheduling (APS) systems

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Abstract

The purpose of this paper is to investigate how the manufacturing process, shop type and data quality, i.e., the shop floor characteristics influence the use of Advanced Planning and Scheduling (APS) systems in Production Activity and Control (PAC). The methodology used is a multiple case study at three case companies with different shop floor characteristics using APS systems for supporting production scheduling. A theoretical framework is developed suggesting how APS is used in the PAC activities and the major aspect to consider. The case analysis shows that APS systems foremost support sequencing and dispatching. In particular, the shop type influences the decision of how often to make the APS run and what freedom to give to the shop floor, whereas the manufacturing process influences how the dispatch list is created. Contrary to literature that presumes that APS systems are most suitable in job shop processes, it is found that the manufacturing process is not a crucial factor for the decision if APS systems are an appropriate investment. Besides, the level of data quality needed depends on a large extent on how the system is used; a high level of data quality is not needed if the APS system is used as a guideline. The paper extends the previous literature concerning APS systems by analyzing how the APS system influences PAC as a whole and increases the understanding for the challenges of implementing APS systems in PAC.

Keywords: production planning and control, advanced planning and scheduling (APS) system, manufacturing process, shop types, data quality

1. Introduction

Today, the majority of manufacturing companies use material requirement planning (MRP) logic in enterprise resource planning (ERP) systems to plan material requirements and release manufacturing orders (Jonsson and Mattsson, 2006). Nevertheless, there are several ways to ensure that orders on the shop floor are executed efficiently. During the years a large number of sophisticated scheduling algorithms have been developed to enhance Production Activity Control (PAC) (Wiers, 2002; Lin et al., 2007), i.e., the set activities required to concert orders released by the manufacturing system to the shop floor into completed orders (Melnyk et al, 1985). With the entrance of Advanced Planning and Scheduling (APS) systems it has been said that operations research algorithms finally can be applied in practice (Gayialias and Tatioplolus, 2004) and the interest for APS as a support in PAC is high (Straube, 2006). Still, research suggests that many APS implementations did not meet the initial expectations (McKay and Wiers, 2003; Stadtler and Kilger, 2005).

APS systems are usually said to support complex planning and scheduling tasks (Rudberg and Thulin, 2008; Setia et al., 2008). But what is a complex task? In literature, PAC is many times related to the type of manufacturing process (Melnyk et al., 1985; Arnold, 1991; Vollmann et al., 2005; Jonsson and Mattsson, 2009). The primary difference is said to stand between line processes compared to job shop processes. PAC is considered more complex in a job shop process than in a line process because of the high number of product variants, the variety of routings, and complex scheduling problems (Arnold, 1991; Vollmann et al., 2005). As a consequence, the use of advanced scheduling algorithms is considered more appropriate in these processes (Jonsson and Mattsson, 2009). Other factors influencing the use of advanced scheduling algorithms in computer based systems is the amount of uncertainty occurring at the shop floor and the ability of operators to perform certain corrective actions. Wiers and Van Der Schaaf (1997) relate shop types to possible autonomy of scheduling tasks and suggest for which shop types APS is most suitable (2009). In a shop floor with many uncertainties and possibilities to handle uncertainties, it is much more challenging to implement an APS system than in a shop floor characterized by little uncertainty and low flexibility as the former requires high discipline of operators and high capabilities of the system. Yet another factor emphasized as important to consider in the use of more advanced scheduling methods is the quality of data. Little et al. (1995) stress that before considering adoption of computerized scheduling tools a manufacturer should consider carefully whether suitable data collection capability is in place, providing timely data of sufficient integrity. The phrase "garbage in, garbage out" has been used since the early days of computing and applies even more today. But how important is the actual quality of data for the use of the APS system?

Most of the literature in the APS area has focused on system setup or the mathematical model (Rudberg and Thulin, 2008) and there is little written about the adoption, implementation and post-implementation aspects of APS systems with a pocketful of exceptions (Wiers, 2009). Zoryk-Schalla (2001) focused on the modelling and implementation process of APS software in an aluminium company. David et al. (2006) reported on the use of APS to solve specifics of scheduling problems in the aluminium conversion industry. Jonsson et al. (2007) explored how APS can be used for solving planning problems at tactical and strategic levels. Rudberg and Thulin (2008) discussed how APS can assist tactical supply chain planning at the Swedish Farmers supply and crop marketing association. Wiers (2002) described the implementation of APS of a steel plant and focused on the integration between ERP and MRP, and Wiers (2009) investigated the relationship between autonomy and APS success in two case studies. None of these studies have focused on all activities in PAC, which is the focus in this study. Even though the main task of the APS scheduling module is to support the planner in the creation of a feasible, near optimal, dispatch list (Hamilton, 2003), we believe that the other PAC activities, i.e., order release, dispatching and reporting will be influenced by an APS implementation. The need for better understanding of PAC as a whole is emphasised by, for example, McKay and Wiers (2003). Besides, none of the studies have linked the manufacturing process with the appropriate use of APS systems. Contrary to most of the PAC related literature, we argue that the use of sophisticated scheduling algorithms should be useful in line processes as complex scheduling problems also occur here. Furthermore, we argue that the importance of data quality depends on how the systems are used. In accordance with Wiers (2009), we believe that the shop type puts restrictions on how APS systems can be accomplished but we extend the findings by investigating the influence of shop type in all PAC activities when APS systems are implemented.

The purpose of this paper is formulated as follows: to investigate how the manufacturing process, shop type, and data quality influences the use of APS systems in PAC. This is done through a comparative analysis among three Swedish companies using APS in different manufacturing processes, shop types, and with different levels of data quality. The remainder of this paper starts by describing how APS is used in the PAC activities and brings up some main aspects to consider. Thereafter, section 3 defines the shop floor characteristics, i.e., the manufacturing process, shop types, and basic data. Figure 1 presents the theoretical framework. In section 4 the methodology used in the research is presented followed by a description of the three case companies included in the study. In section 6 a cross-case analysis is conducted regarding how APS is used in the PAC activities and in which way the shop floor characteristics have influenced the activities. Finally, in section 7 the findings are discussed and future research implications are given.

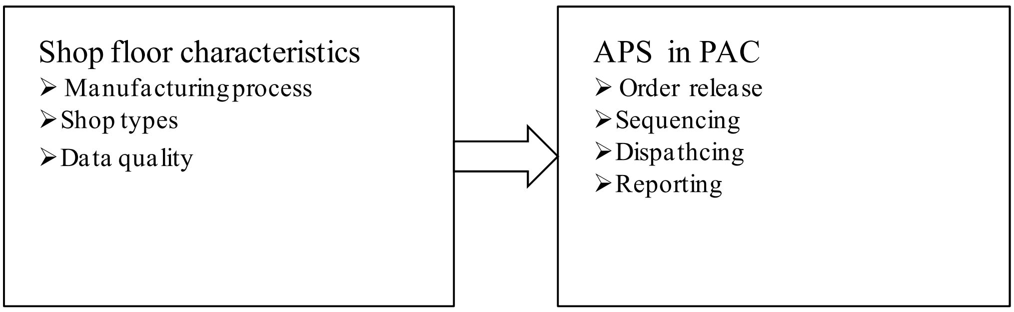

Figure 1: The theoretical framework

2. The use of APS in PAC

There are many software vendors offering APS systems; for example, SAP, i2, Manugistcis, Oracle and Lawson (Kreipl and Dickersbach, 2008). Still, it is possible to find a common structure in commercial off-the-shelf APS systems according to the planning level and the supply chain process the software module is supporting (Stadtler and Kilger, 2005). The main task of the APS scheduling module is to support the planner at the short term planning level in creating a feasible, near optimal, dispatch list considering all modelled constraints and objectives (Hamilton, 2003). In this paper a feasible dispatch list will be defined as a list where the sequences suggested are possible to follow and where times suggested are possible to hold. In this chapter the use of APS in the PAC activities, i.e., order release, sequencing, dispatching and reporting will be described.

2.1 Order release

The first activity in PAC is order release, which concerns order release control, material availability check and generation of the shop packet (Jonsson and Mattsson, 2009). The use of APS in this activity will start when the released manufacturing orders generated at the order planning level are downloaded from the ERP system or the APS production planning module to the APS scheduling module. Whereas the manufacturing orders always contain information about start times, due times and quantities, information concerning how far in the future orders should be released to the shop floor and if capacity, tools and material have been considered differs from case to case. If the ERP system relies on MRP for material planning, consideration is only taken from the demand side as MRP assumes infinite capacity. A rough level of capacity considerations can be taken if a master production scheduling process has been carried out before running the MRP. However, to achieve perfect synchronization, consideration must also be given to capacity shortage and disruptions in the inbound material flow, which is the case if APS is used at the order planning level (Mattsson and Jonsson, 2009).

2.2 Sequencing

At each workstation in a work centre, every time a job is completed, a decision has to be made about which order will be processed next: this decision is referred to as sequencing (Berglund and Karlund, 2007). The APS system produces a dispatch list of operations for each work centre in the sequence in which operations are expected to be carried out where available capacity is considered (Jonsson and Mattsson, 2009). How often the APS is run differs from case to case. A dispatch list can be generated with aid of simple priority rules, e.g., shortest operation time, first in, first out or more sophisticated algorithms, e.g., least difference between remaining time to due time and accumulated remaining operation time and critical ratio. Common scheduling heuristics in APS systems are versions of genetic algorithms and constraint-based programming since optimization algorithms cannot calculate the actual optimum within an acceptable timeframe (Kreipl and Dickersbach, 2008). One advantage of using heuristics is that they are able to provide good solutions for complex production environments; one disadvantage is that it in most cases is difficult to retrace the results. The importance of understanding how the resulting scheduling is calculated should not be underestimated (Taal and Wortmann, 1997). The issue of transparency is often referred to as the black box problem (Stoop and Wiers, 1996). APS systems are based on many assumptions in order to enable economically feasible models (Stadtler and Kilger, 2005). If the models are invalid the lists will be adjusted manually with the consequence of suffering the performance criteria the lists were based on (Stoop and Wiers, 1996).

2.3 Dispatching

The implementation of a dispatch list, i.e., the execution of the operations at the shop floor is often referred to as dispatching (Stoop and Wiers, 1996). Important to consider in this activity is what information the dispatch list includes and how the shop floor gets information about any changes in the planned requirements. Considerations should also be taken regarding what freedom the personnel have to set priorities and choose the sequence. In general, when an APS system is implemented, planning and scheduling decisions are transferred from the shop floor to the APS system (Lin et al., 2007). As a result, there can be disagreements between the scheduler and the shop floor about the autonomy permitted to the shop floor post implementation (Wiers, 2009). There are different views both in practice and in theory of how much autonomy should be allocated to the shop floor (Vollmann et al., 2005). It could be argued that since operators are faster and better at handling disturbances, autonomy should be allocated to the shop floor. Besides from a motivation point of view, the operators on the shop floor should be able to exercise some control of their work (Wiers and Van der Shaaf, 1997). However, from an optimisation point of view, it could be argued that decisions should be centralised as much as possible. According to Little et al. (1995), lack of discipline from operators is a major problem; in order to gain benefits from the production, schedule operators should follow the dispatch list slavish. Some APS systems suffer from the so-called "final-state" problem, meaning that small changes in the status of the shop floor cause major changes in the production schedule (Kreipl and Dickersbach, 2008). If this is the case, operators might circumvent the dispatch list.

2.4 Reporting

The fact that manufacturing orders and operations have start and finish times does not mean that they necessarily will be started or completed at the times stated. Thus, information pertaining to the progress of orders on the shop floor should be reported to the higher planning levels so that they can be aware of what is happening on the shop floor as well as intervene to correct possible problems. There are different ways of reporting, spanning everything from a situation where operators only report the entire order to a situation where real operation times are reported. Reporting may take place with the aid of barcodes or manually direct in terminals connected to the ERP system or different types of cards. Feedback should also be given to the shop floor on how well they perform.

Table 1: The main aspects when using APS in PAC

Activities in the production scheduling process	**Aspects to consider**
Order release (orders downloaded from the ERP system or the APS production module to the APS scheduling module)	-How far in the future are orders released to the shop floor? -How is consideration taken to capacity, tools and materials before, under and after the APS run?
Sequencing (the dispatch list is created)	-How often is APS run? -How is the dispatch list created?
Dispatching (the dispatch list is implemented)	-Which information does the dispatch list include? -What decision freedom is given to the shop floor?
Reporting	-How does the personnel report? -How is feedback given to the shop floor?

3. Shop floor characteristics

In this chapter three shop floor characteristics are presented derived from literature in manufacturing planning and control and which should have an influence on the use of APS in PAC.

3.1 Manufacturing process

How the activities in the PAC process are carried out, and their importance, is largely determined by the characteristics of the manufacturing process (Vollmann et al., 2005). The primary differences are between line processes compared to job shop processes (Jonsson and Mattsson, 2009). The line process is characterized by a line layout, high volumes of few or similar products and short set-up times and manufacturing lead times (Vollmann et al., 2005). In such environments, order release and sequencing takes place almost simultaneously. Sequencing is considerably easier in comparison with manufacturing in a job shop, since the planning point is only the start of the line and not the individual machines or work centers (Jonsson and Mattsson, 2009). In a job shop process the work flow depends on the design of a particular product and machinery and work centers are usually grouped according to the function they perform. The volumes and the production variation are smaller whereas set-up times and manufacturing lead times are higher than in-line processes. The differences among the PAC activities are more clear-cut and sequencing plays an important role and priority decisions must be made. As a consequence of the increased complexity that the job shop environment places on the production scheduling process, many researchers argue that it is mainly in the job shop context that an advanced system support is necessary (for example, Vollmann et al., 2005; Jonsson and Mattsson, 2009).

3.2 Shop type

Wiers (2009) has related different shop types based on the amount of uncertainty and human recovery to the successful use of APS systems. The four different types are smooth shop, stress shop, social shop, and sociotechnial shop. Uncertainty is, for example, machine breakdowns, illness of operators, unavailability of tools, rush orders, scrap, rework, fulfilment of sequencing rules and measurement (Stoop and Wiers, 1996). Human recovery means the ability of the operators to use flexibility as, for example, alternative routings, overtime, part time labour and lot splitting to compensate for disturbances. A smooth shop floor characterized by low uncertainty and no human recovery offers the best promise for the implementation of an APS system. The shop is stable; optimization can be performed with precise operation timing and sequences. In the social shop, there is low uncertainty but operators in production can make detailed scheduling decisions. The APS system might suggest detailed schedulers, but they are unlikely to be followed, which means that the APS implementation will be more challenging that in the smooth shop. The stress shop is characterized by high uncertainty but no human recovery. The schedule needs to be revised frequently and APS can support the scheduler in making changes to the schedule and receiving feedback on the shop floor. In the sociotechnical shop, there is high uncertainty and human recovery. According to Wiers (2009), a classical error is to implement an APS system that creates detailed schedules, which are being ignored by the shop floor anyway- most likely with good reason.

3.3 Data quality

Only a subset of the data available in the ERP system is used by the APS system, depending among other things on the scheduling algorithms used. It is interesting to know which basic data is used by APS, e.g., item data, bill-of material data, routing data and work centre data and how well it corresponds with actual data (Jonsson and Mattsson, 2009). APICS (2007) highlights the importance of the collection and validation of data in all planning activities. However, the need for accurate data is especially high when working with finite capacity and real-time planning. Berglund and Karltun (2007) emphasise the ability of the scheduling software system to provide sufficient data in order to create prerequisites for the scheduling process. According to Little et al. (1995), the use of more advanced scheduling tools is likely to produce benefits only if operated in a structured and disciplined manner as these systems relay a significant volume of detailed and accurate data.

4. Methodology

The use of APS systems in PAC was studied in three companies. These companies were selected according to two criteria: (1) that the companies used a scheduling module from one of the largest APS vendors on the Swedish market and (2) that the companies had different types of shop floor characteristics. The reason for why it was important that the companies used a module from the same APS vendor was to make the comparison as straightforward as possible as well as to be able to use previous literature and experiences. The reason why the companies needed to have different shop floor characteristics was to increase the understanding for how the same module could support different shop floor characteristics.

Various methods were used to collect data from the case study from February to October of 2009: interviews, on-site visits, company internal data and presentations. To the utmost possible extent, we wanted to interview people that were both directly involved in creating the dispatch list and people that used the output. In all cases APS was more or less a one user system and the scheduler/s were the ones that worked in creating a dispatch list. This person/s was also the key informant at all case companies. At all companies one or several foreman was interviewed and at two of the case companies a number of operators were interviewed. It was not possible to interview the operators at case company C; however interviews were conducted with the supply chain organisation, the scheduler, and the foreman. Besides, site visits were made at the shop floor where the author could walk around and ask the personnel some short questions, which increased the author´s understanding of how APS was used at the shop floor at case company C. The interviews were based on the questions in Table 1 and the shop floor characteristics and interviews were in general around half an hour, except from the key informants where interviews were much longer. Research protocols were designed and used to improve reliability and validity (Voss, 2002). The protocols were tested in initial interviews with key respondents. Respondents were frequently asked the same questions to enhance the reliability of the data and the notes from the interviews were sent to the interviewees for feedback and for checking the data. Following the series of interviews, each company was written up as a case study report which was then validated by the interviewees.

The data analysis started by a within-case analysis with the overall aim to become familiar with each case as a stand-alone entity (Eisenhardth, 1989). Thereafter a comparison between the three companies was made with the aim of increasing the understanding for the signification of the shop floor characteristics in the APS system supported PAC process.

5. Company description

In this section the case study companies are briefly described with help of the shop floor characteristics defined in section 4. Furthermore, the use of APS systems in the PAC activities and the experiences from the interviewees is presented with the help of Tables 2-4.

5.1 Drilling machine manufacturer

Case company A is a division of the business area construction and mining technique at a Swedish industrial concern and develops and produces drilling machines. Most products are produced to stock. The manufacturing process could be characterized as a typical job shop with its 40 work centres consisting of several machines and operators grouped according to the function they perform. The order sizes are between two and 200 and there are over 200 different product variations. The set-up times are between half an hour to two hours and the manufacturing lead time is on average nine days. The shop floor could be characterized as a sociotechnical shop as there are high uncertainties; for example, tools are out on loan to subcontractors, there are machine breakdowns, and rush order in the same time as there are many options for handle uncertainties; it is, for example, possible to run jobs at several machines and split orders.

An APS production scheduling module was implemented in 2002 in order to reduce the tied-up capital and lead times and to improve the delivery precision. According to the scheduler, tied-up capital and lead times have decreased and delivery times have improved since the APS system was implemented. Still, it was many factors that influenced the result; for example case company B increased sales during the period and invested in new machines – which in turn influenced the inventory levels and the lead times. The organisation consists of two schedulers, two foreman and 100 operators. The APS system utilizes all types of basic data but the most important data is capacity figures and operation times for planning. Operations times come from estimated set-up times and run times by operators. The capacity is measured in man-hour per period. According to the scheduler and the foreman, the quality of data could be better.

The use of the APS system at case company A in each activity in the PAC activities and the actors' experiences are presented in Table 2.

Table 2: The use of the APS system in the PAC activities and the actors' experiences

Activity	**Use of the APS system**	**Experience**
Shop order release	-Released orders concern the nearest five months. - Scheduler manually checks if material and tools are available. Consideration taken to capacity at order planning level.	-The scheduler thinks that it would be possible to use the APS system to a higher extent. For example, hand over the material and tool check to the APS system and analyze why orders are delayed.
Sequencing	-APS is run every morning (takes 1.5h) -The dispatch list is generated with the help of priority rules. Number one is earliest due data first. Consideration is taken for capacity in machines and personnel. However, consideration is not taken for maintenance and the prototype shop in the capacity calculations.	--Scheduler points out the problem of not including maintenance and prototype shop in the calculation of available capacity. Besides, it is a problem that assumptions are made in the model that do not correspond with reality; for example, that orders cannot be split.
Dispatching	-The dispatch list includes information about which operations are to be done for the nearest five months, the status of operations, due dates, material status, and how many hours the operation is supposed to take. The dispatch list is transferred to terminals connected to the ERP at each work centre where information is given in real time. -The rule strongly communicated from the planning organisation is to always follow the dispatch list.	-Many operators welcome the possibility to see far in the future as this opens up for being better prepared and planning in advance. -Most of the operators think that the dispatch list many times suggests a strange priority. -One problem is that the dispatch list can look completely different from day to day. The foreman would like to freeze the list for at least three days; he says "a plan with many changes leads to manually adjustment of the list." -Some operators execute the dispatch list after their own priority rules. Some talk with the scheduler or foreman before deviating from the list, and others do not. When disturbances happen at the shop floor most operators try in the first place to solve the problem him/herself. Usually a disturbance at the shop floor does not lead to a reschedule in the APS system.
Reporting	-The operators report when an operation has started and is completed, and on manufactured quantities and scrapped quantities. If the operation took longer than it was supposed to, some operators register this in the ERP system but others do not. The operators report manually in the ERP system by clicking at the operation and choosing the status number and type in the quantities.	-Many operators stressed that the operation times in the dispatch list did not correspond with real operation times. Still, most of them consider that it is important that the operation figures are updated. According to the scheduler and the foreman, the operation times could be improved a lot.

5.2 Garage door manufacturer

Case company B is a manufacturer of garage doors. It consists of three production sites whereof the production site in Sweden is studied in this paper. The manufacturing of garage doors starts when the customer orders are received.

The customer lead time is 11 days. The manufacturing process could be characterized as a typical line process consisting of ten work centres arranged according to routing. The manufacturing process is automatic and the material required is connected to each operation. The volumes are high and the product variants few. The set-up times are between a couple of minutes to 30 minutes and the manufacturing lead time is one to two hours. The shop floor could be characterized as a smooth shop as there is low uncertainty and low flexibility to cope with it.

An APS production scheduling module was implemented in 2003 as the production site needed a system that could optimize and sequence the process. At the beginning it was very problematic as the material plan and the production plan were not synchronised but in 2006 a new consultant entered the project and one understood that the problem was not the APS system but lack of APS systems knowledge. The use of the APS system has resulted in a simplified way of working, reduced administrative lead time, minimised material shortage, reduced inventories and a synchronized material and production plan. The organisation consists of one scheduler, two foreman, two group leaders, and 54 operators. The most important data is the data that is required to set the so-called configuration keys, that is the keys set up to make the sequencing in the APS system. The data quality is, according to the interviewees, very high. Capacity is not a problem and the company has together with the union put up a “time bank” so that time off is granted if there is nothing to do but if there is a lot to do there are extra hours to take from the time bank.

The use of the APS system at case company B in each activity in the PAC and the experiences of doing so are presented in Table 3.

Table 3: The use of the APS system in the PAC activities and the actors' experiences

Activity	Use of the APS system	Experience
Shop order release	-Released orders to the shop floor concern the customer lead time, i.e., 11 days. -Consideration has been taken to capacity before the APS run at the monthly S&OP meeting. Before the dispatch list is sent to the shop floor the scheduler manually checks if material is available.	-According to the scheduler there is no reason to schedule orders outside the lead time of 11 days as it could lead to over producing and inventories. Instead, the schedulers try to wait as long as possible in order to process as many similar orders as possible as the company wants to avoid one piece flow.
Sequencing	-APS is run four times a week (takes about 30 minutes) -The APS system is used to sequence one operation, i.e., "process line" and configuration keys are used to set the sequence. First, all panels with the same height are scheduled; thereafter comes the model, the colour and last if the port has some additional features for example a window. Material planning and capacity planning is taken away from the APS system. The APS system is only a tool for sequencing.	-Schedulers point out that "even if the APS system is not used to its full potential it is a very important tool for the shop floor performance, which we could not be without." -Operators think that it is easy to understand why the dispatch list looks like it is impossible to change the heavy roller too often and therefore it is important that orders of the same type are scheduled together.
Dispatching	-The dispatch list includes information about which operations are to be done for the nearest 8 days, start times, due times, the panel´s characteristics, configuration number, and which car the port will be transported with. The dispatch list is transferred to a custom made production system which is online and occurs at terminals at each operation. The production system controls all machines and manages the automatic reporting. -Operators have some freedom to decide if, for example, model A should be processed before model B if it is within the group with the same height.	-Operators stress that they follow the dispatch list as far as possible and that the list is of a high quality. Sometimes they do some small changes depending on the status of the shop floor. -Operators are happy with the information they receive in the dispatch list: "all we need is displayed in the production system." -As disturbances are low there is rarely any reason to make a new APS run; instead they are handled at the shop floor. Sales managers might succeed in persuading the scheduler to reschedule because of a rush order, but only on rare occasions.
Reporting	-The reporting is automatic. When a customer order is registered in the ERP system a unique configuration number is created. The unique number is read automatically, operation by operation as the batch is processed.	-The scheduler thinks that the analytical capabilities of APS systems are limited and RSD uses another program to analyse data.

5.3 Cutting tool manufacturer

Case company C, manufactures and globally markets metal cutting solutions. The company consists of several production sites which mainly produce different products. Still, many products are processed in many steps and involve many production sites. The focus in this paper will be on the production site in Fagersta. Customers are promised deliveries in 24-48 hours and over 90% of the products are made to stock. The manufacturing process is a mix of a job shop and a line process. The work centres are arranged according to the routing of most products and include on average thirteen operation steps. Within each work centre there are many different types of machines that do a variety of works. The volumes are high (average order size is 1500) and the production variants around 7000. The set-up times are between a couple of minutes to three hours and the manufacturing lead times are 21 days on average. The shop floor could be characterized as a sociotechnical shop as there is high uncertainty and there are many ways to cope with them on the shop floor. For example, orders can be run at parallel machines and it is possible to split orders. The operators are also flexible and can work in different work centres.

An APS production scheduling module was implemented in 1997 with the aim of reducing the lead time and increasing the utilization rate in machines. According to the scheduler both these goals have been met but case company C also increased the flexibility as a consequence of the capabilities in the APS system to convert the plan after demand variations. The organisation consists of one scheduler, one foreman, 15 group leaders and 120 operators. The most important data is the data connected to the parameters sat in the model, i.e., set-up times, operation times, capacity, queue times, and inventory on hand. The data quality is relatively high and according to the scheduler, case company C "is measuring everything that can be measured." That data is correct is controlled ones a year. Capacity is measured as hours and units per article.

The use of the APS system at case company C in each activity in PAC and the experiences of doing so are presented in Table 4.

Table 4: The use of the APS system in the PAC activities and the actors' experiences

Activity	Use of the APS system	Experience
Shop order release	-Released orders to the shop floor concerns orders far in the future. -Before the orders are downloaded to the APS system the scheduler has made sure that materials and tools are available. Capacity consideration is taken at the order planning level.	-According to the scheduler, the APS system is a black box helping the factories produce a feasible dispatch list. -A problem with the APS system is according to the scheduler that it is difficult to extract information. For example, it is difficult to transfer data from the APS system to MS Excel.
Sequencing	-APS is run three times a day (takes around 15 minutes) and generates a dispatch list for four production sites with dispersed locations. -The the APS system is used to sequence one operation, "The Press". All previous and following operations emanate from the sequence of "The Press." The sequence used in "Pressing" is based on a number of keys. "The Press" is sequencing on geometry. -Consideration is taken for capacity in the machines. Some consideration is taken for maintenance	-The priority rules in the APS system are based on experiences and according to the scheduler it is logical and appropriate. -Except "The Press" there is one more operation with long setup times and this operation should also need a sequencing tool.
Dispatching	-The dispatch list includes information about start times, due times, in which machines the different product should be processed and how long it should take. -The APS system generated dispatch list is sent to the custom made reporting system connected to the ERP system. The dispatch list is online and occurs at terminals with each work centre. -There is some freedom to circumvent the dispatch list.	-The foreman keeps an eye on rush orders, customer orders, and orders that are late. -Operators keep to the dispatch list most of the time. -The foreman stresses that the APS system are a good engine to generate the dispatch list. Still, it is very important that the parameters are correct. Garbage in-garbage out! -A disturbance at the shop floor does not lead to a new APS run but if the disturbance is large it is usually considered in the next APS run. It is also possible to type a message directly into RAPS to inform everybody about the disturbance.
Reporting	-The operator reports as soon as they begins a job at a machine or takes over a job. The operator also reports when a job is finished or when he/she is finished for the day. For reporting, the operator scans his/her personal card. -Information about how well respectively work centre accomplished the dispatch list is returned every week.	-The reporting is working fine according to the scheduler and foreman. The reason is that that the reporting is individually and if an operator makes repeated mistakes the operator will be observe and given education. -According to the scheduler, work centers with small setup times and many disturbances get off light if they circumvent the dispatch list, whereas work centers with large setup times should be ashamed.

6. Analysis

In this section a cross-case analysis regarding how APS systems are used in each activity and in what way the shop floor characteristics has influenced the PAC activities is conducted.

6.1 The influence of the shop floor characteristics in the order release activity

In the order release activity APS systems were not used to consider the availability of materials and tools at the case companies. Instead, the material and tool check was handled manually by the scheduler. Consideration for capacity was taken at a higher planning level at all case companies but none of the companies used finite capacity planning in the order planning level. How far in the future manufacturing orders were released to the shop floor differed among the cases. Case company A released orders for the next coming five months, case company B for the coming 11 days and case company C for a couple of months. The problem with releasing orders far in the future became evident; at case company A many operators used this information to plan in advance, resulting in deviations from the dispatch list. It did not seem that the order release activity was influenced by the shop floor characteristics, which does not come as a surprise as APS systems were not used so much in this activity. The scheduler at the companies stressed that they could have used APS systems to a larger extent; for example, to automate the material check and analyze why orders were delayed.

6.2 The influences of the shop floor characteristics in sequencing

There were two main aspects to consider in the sequencing activity; how often the APS system was run and how the dispatch list was created. At case company A, the APS system was run every day, at case company B four times a week and at case company C four times a day. While it is difficult to give some direction for what is an appropriate number of APS runs, it became evident that the shop type influenced the choice of how often to make the runs. In case company B, with a smooth shop characterized by low uncertainty and human recovery, there was no reason to make the APS run more often than to guarantee that released orders were performed within the given customer lead time. At case companies B and C, on the other hand, with a sociotecnical shop characterized by high uncertainty and human recovery there could be good reasons for running APS systems more often than that. If autonomy is given to the APS system, as at case company A, it is important that the dispatch list is absolutely correct, which implies high data quality, and that operators keep strictly to the dispatch list. It also implies that the APS system must handle uncertainties and a new APS run needs to be made every time a disturbance occurs. Otherwise the dispatch list will be incorrect and difficult (inappropriate) to follow. At case company A uncertainties were not handled by the APS system resulting in frustration at the shop floor and that operators many times used their own priority rules to execute the orders. The strategy at case company C was a bit different, here operators were given some more freedom and the list was used more as a guideline. A disturbance at the shop floor did not immediately lead to a new APS run but APS was run more often than at case company A and disturbances that had not been solved before the next run were included in the APS run. According the foreman at case company C operators followed the dispatch list most of the time. Another factor that was found to influence the choice of how often to make the APS run was the capability of the APS system. It became apparent, in case company A, that the APS system suffered from the final state problem and that there is a tradeoff between frequent rescheduling, leading to a nervous behavior of the system and no rescheduling leading to an incorrect dispatch list.

The second aspect in sequencing concerned the creation of the dispatch list. The dispatch lists at the three case companies were designed in different ways depending on the problem the company wanted to solve, which in turn to a large extent depended on the manufacturing process. At case company A the APS system was used as a tool for assigning priorities to orders waiting in queue at a given work center with the aim of reducing lead times and tied up capital and improving delivery times. To do so, priority rules and finite capacity scheduling was used. The problem the APS system solved at case company A is a typical problem of a job shop process. At case company B the problem was that one of the operations in the line process had sequent dependent setup times limiting the performance of the entire system. An APS system was therefore used to decide the optimal sequence at the bottleneck and all previous and following operations emanated from the sequence in this bottleneck operation. Case company B did not suffer from capacity shortage and therefore the functionality of finite scheduling was not activated. The problem at case company C was similar to case company B. One of the operations in the work center suffered from sequent dependent setup times and the company needed a tool to set the sequence in this operation. Case company C suffered from capacity shortage as case company A, and as a result consideration to available capacity was taken when sequencing the orders. In addition, case company C included more than one production site in the model as many products needed to be processed at several steps involving more than one production site. Whereas the manufacturing process influences the design of the dispatch list, the scheduling algorithms used to generate the dispatch list sat the frame for which basic data was of the most importance. At case company B for example the sequence was dependent on the characteristics of the panels, and therefore data figures such as height, model, colors, and if the panel should include additional features were of great importance and needed high quality. On the contrary, capacity was not a problem at case company B and as a consequence there were not as high of demands on the quality of operation times and capacity figures as there were for the other two case companies.

6.3 The influences of the shop floor characteristics in dispatching

In the activity dispatching there are in particular two main aspects to take into consideration: what information the dispatch list includes and what decision-making freedom should be given to the shop floor. At all companies the dispatch list was transferred back to the ERP system and visualized in real time at terminals at each work center or operation. The operators and foreman worked directly in the ERP system at case company A and at customized production systems connected to ERP at case company B and C. In other words none one of the operators or foremen worked directly in the APS system. This being so, the information given at the terminals included much more information than the information derived from the APS system and it was difficult for operators to separate which information came from which system. Still, in general, the operations at the three case companies were happy with the information visualized in the dispatch list. The shop floor characteristics did not seem to have a direct influence on the information visualized; instead, this was more a consequence of system integration and information technology. It was, for example, beneficial and highly valued among operators that the dispatch was online so that operation changes in status and priority could be made when an operation was completed in the following operation's dispatch list, and that the addition or cancellation of orders popped up in the dispatch list immediately.

The second aspects concerned the decision freedom to the shop floor. The rule communicated from the planning organization at case company A was to always follow the dispatch list, whereas at in the other case companies it was okay to deviate from the list on special occasions. The decision of which freedom to be taken is strongly connected to the quality possible to obtain in the dispatch list. If it is possible to obtain a high quality it is possible for operators to follow the dispatch list and there is no use for deviations. But, if the quality of the list is defective it is probably better to allow the shop floor to tune the final work sequence. This was, for example, experienced at case company A where many operators stressed that the dispatch list suggested a strange priority and therefore circumvented the list in order to keep a high utilization rate. How high of quality that is possible to obtain is influenced by the shop type and the system´s capability as discussed before, but also the data quality in to the system as the foreman at case company C points out, and the model design. It is important that the system represents the shop floor as far as possible. At case company A the scheduler pointed out one example of how the modeling effects the quality of the dispatch list, i.e., the model was based on the assumption that orders could not be split, which was not the case in reality.

6.4 The influences of the shop floor characteristics in reporting

The two main aspects to consider in reporting are in what way personnel report and how feedback is given to the shop floor. At case company A operators reported manually in the ERP system when an operation had started and was completed, at case company B operators did not need to do anything as the reporting was completely automatic, and at case company C operators reported as soon as they began a job, took over a job, when the job was completed or when they were finished for the day. Considering the fact that the most important data in the APS system at case company A was operation times and capacity figures, it should be important that the operators really report the actual operation times. As it is now, operators do not always fill in the exact times, which results in the times given by the system not corresponding with reality. In other words, it seems to be a relationship between the way the personnel should report and the scheduling algorithms used. How the personnel should report is also influenced by the way the APS system is used; if autonomy is given to the APS system and the dispatch list should be carried out exactly, it requires high discipline of the operators to report every little happening. Feedback was given every week to the shop floor at the case companies on how well they had accomplished the dispatch list. However, it was only at case company C that the operators could be connected to the mistakes and case company C was the only of the three case companies where deviations were punished. As one would expect, it was found that the quality of the input data, hence the quality of the dispatch list, was influenced by the activity reporting. The data quality at case company A could be better according to the scheduler and foreman and the operators stress that the operation times given by the dispatch list did not always correspond with actual operations time. One reason for this might be that operators did not report every little happening and a loss of any rewarding system. At case companies B and C the data quality was perceived to be higher and those companies had worked more with reporting and feedback than case company B.

7. Discussion

From the case analysis it was found that the identified shop floor characteristics: manufacturing process, shop types and data quality influenced the APS systems supported PAC process. However, when looking in detail into the four PAC activities it became clear that the level of influence from the shop floor characteristics was different in the activities (Table 5). In the order release activity none of the shop floor characteristics was an important factor in how the activity was carried out. In the sequencing and dispatching activities the shop type and manufacturing process influenced the question of how often to run the APS system, how to create the dispatch list, and which information freedom to give to the shop floor. It was also found that the design of the dispatch list sat the frames for which data were of the most importance, hence, in need of high data quality. None of the shop floor characteristics influenced the activity reporting; instead the way the operators reported influenced the data quality, which in turn influenced the quality of the dispatch list.

Table 5: The influences of the shop floor characteristics on PAC activities in the three case companies

PAC activities	**Shop floor characteristics**		
	Manufacturing process	Shop types	Data quality
Order release			
Sequencing	The manufacturing process influenced how the dispatch list was produced.	The shop type influenced how often to conduct the APS run.	How the dispatch is produced set the frames for which data is of importance and is needed to be of high quality.
Dispatching		The shop type influenced which decision freedom to give to the shop floor.	
Reporting			Data quality is influenced by the reporting.

In the manufacturing planning and control literature it is usually presumed that the use of advanced scheduling algorithms is best suited for solving complex problems in a job shop process. Jonsson and Mattsson (2009), for example, stress that sequencing in a production line is easier than in a job shop and that detailed dispatch lists are needed mainly in a job shop environment. Vollmann et al. (2005) argue that production scheduling systems are founded on the premises of job shop manufacturing. In this paper, case company A was characterized as a typical job shop process where the use of an APS system should be appropriate if following the discussion obtained from theory. The interviewees also perceived that the goals of implementing an APS system were released, implying that the APS system investment has been appropriate. So far everything is fine, but the interviewees in the other two companies also perceived that the goals of the APS systems were meet and either of these manufacturing processes could be characterized as a typical job process. In other words, from the evidence of this study it seems as the manufacturing process is not a crucial factor for deciding if APS system is an appropriate tool or not. An APS system can be an excellent support in a line process as problems difficult to solve manually and that need some support in the form of advanced scheduling algorithms are also present in this manufacturing process. At one of the case companies in the study, an APS system was used to decide the optimal sequence of one operation in a line process with sequence dependent setup times as the operation limited the performance of the entire system.

In accordance with Wiers (2009), the case analysis showed that the shop types had a large influence on the APS systems usage in the PAC process. We identified two main aspects where shop type is of particular importance; in the decision of how often to make the APS run and in the decision of what freedom should be given to the shop floor. In an ideal word the dispatch list generated from the APS system corresponds perfectly with reality and as long as orders are executed as dictated in the system the largest possible performance will be achieved. However, in reality this is never the case and the challenge is to make the dispatch list correspond enough with reality so that people can trust in the dispatch list. In the smooth shop, uncertainty is low and there is not much flexibility to cope with uncertainties on the shop floor. Therefore, there is no need to reschedule over and over again to cope with, for example, rush orders. Instead, it is enough to run APS so that orders are released within the time to manufacture products within the promised customer lead times. The situation becomes much more complicated when there are many disturbances on the shop floor and plenty of options for coping with them as at two of the companies in the study. The question here is to either hand over autonomy to the APS system and, if doing so, make a new APS run every time a disturbance occurs or use the APS system as a guide and hand over the autonomy of handling disturbances on the shop floor. Which decision to make depends on the quality of the dispatch list, which in turn depends on a number of factors. In the case analysis it was found that APS systems suffer from the "final state" problem which corresponds with the findings in previous studies (Kreipl and Dickersbach, 2008). This being so it was inappropriate to conduct the APS run after every single disturbance on the shop floor as it caused major changes in the dispatch list. Other factors influencing the quality of the dispatch list identified in the study was the level of data quality, modelling of the APS system, and discipline of operators. It was found that it is difficult to obtain a high quality of the dispatch list in a sociotecnical shop and the question of how often to run APS and which freedom to give to the shop floor is difficult to answer. These findings correspond with Wiers (2009) that concludes that implementing an APS system in a sociotechnical shop is a challenging task.

It is usually presumed that a high quality of data is a must if making more advanced scheduling tools successful (Lin et al., 1995). However, the case analysis in this paper shows that the level of data quality depends on how the APS system is used. If the APS system is used as a guide, then there is no need for very high quality, but if it is used to give detailed schedules with precise operation timings and sequences, a high data quality is very important. An interesting reflection is that the best climate for an APS usage is in the smooth shop and the case company in this study characterized as a smooth shop was the company with a line process. It is commonly known that one characteristics of a line process is that there is little flexibility to cope with uncertainties whereas in the job shop there is usually high flexibility. Following this logic, one might wonder if the line process offers a better promise for the implementation of an APS system than a job shop. Still, one should remember that the full potential of the APS system was not used in the job shop, and maybe there is more to gain in a line process if one succeeds in successfully implementing and using the APS system.

8. Conclusion

The purpose of this paper was to investigate how the manufacturing process, shop types and data quality influenced the use of APS systems in production activity control (PAC). Three case companies with different types of manufacturing processes, shop types and level of data quality, using a scheduling module from a large Swedish APS vendor were selected. In the case analysis it was found that the shop floor characteristics influenced the PAC activities. In particular the shop type and data quality influenced the decision of how often to make the APS run and what freedom to give to the shop floor, whereas the manufacturing process influences how the dispatch list was created. The data quality was in turn influenced by the way the personnel reported and the feedback given to the shop floor.

It was argued that the manufacturing process was not a crucial factor in deciding if or if not an APS system should be implemented. Instead, it is important to identify the scheduling problem and investigate if the problem is suitable to handle with an APS system. It was found that there is no end in itself to obtain a very high data quality, instead it depends on how the APS system is used. If autonomy is given to the APS system and operators are said to follow the dispatch list slavish it is important that the dispatch list is of a very high quality, and as such it requires a high level of data quality, high discipline of operators, good modeling, and high capability of the system. However, if the dispatch list is more used as a guide line, than the need of high data quality is reduced. The decision of which direction to walk is much decided upon the shop type, as it is a very challenging task to uphold a feasible dispatch list in a shop type characterized by much uncertainty and flexibility of the operators to cope with this uncertainty. Not least as it was found that some APS systems suffered from the final state problem making very frequent rescheduling inappropriate.

Although the focus in this paper was to study how the manufacturing process, the shop type, and the data quality influenced the use of APS systems in the PAC process we came across many other factors of importance. In future studies it would be interesting to study, for example, the importance of modeling in using APS systems. Besides, it would be interesting to see how the black box problem and level of feedback affects the motivation of operators, and the quality of the dispatch list. In this study none of the cases made use of finite capacity planning at the order planning level, still APS systems allow for finite production planning which in practice means that the MRP system is replaced by an APS module at the order planning level. It would be interesting to investigate the pros and cons of integrating finite production planning and scheduling in the APS system and what is important to consider when doing so. Yet, an interesting issue for further research is to study the capability of the APS system, for example how APS system can handle uncertainties.

9. References

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